Fast X-ray imaging of the NSTX plasma with a Micro Pattern Gas Detector based on GEM amplifier

Collaboration **PPPL - JHU - ENEA**

Danilo Pacella

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Permanent address : ENEA, C.R. Frascati, Italy

8th International ST workshop **Princeton, 11/18/2002**

Plasma imaging with
Micro Pattern Gas Detectors.

D. Pacella, ENEA-Frascati (Italy) – Visiting Scientist at JHU (MD, USA)
R. Bellazzini INFN - Pisa (Italy)

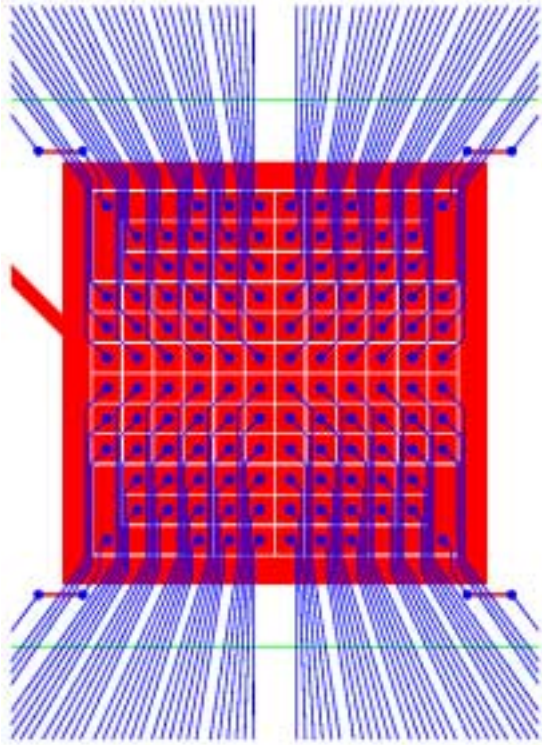
An innovative fast system for X-ray imaging has been developed at ENEA Frascati and INFN Pisa (Italy). It is based on a pinhole camera coupled to a Micro Pattern Gas Detector (MPGD) having a Gas Electron Multiplier (GEM) as amplifying stage. This detector (2.5cm X 2.5cm active area) is equipped with a 2-D read-out board with 144 pixels with high speed asynchronous individual counting capability.

The system has been successfully tested on the Frascati Tokamak Upgrade (FTU, Italy)) and on the National Spherical Tokamak eXperiment (NSTX) at Princetown (US). Time resolved, two-dimensional, high rate (up to 50KHZ framing rate) X-ray images of the NSTX plasma core will be presented.

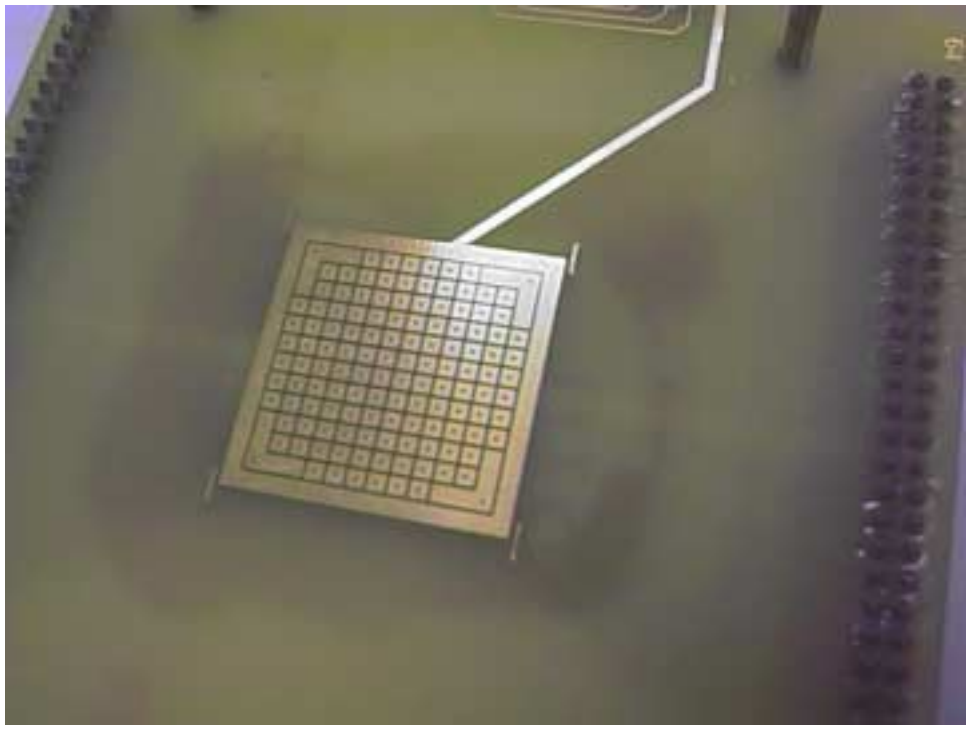
PARALLEL READ-OUT

To achieve the maximum rate capability, the read-out is divided in $4mm^2$ pads that work as independent X-ray counters.
Each pad is provided with a whole electronic chain:

Pre-amplifier ⇒ Amplifier ⇒ Discriminator ⇒ Gated counter



Printed circuit board
128 pixels (2.5 x 2.5 cm^2)



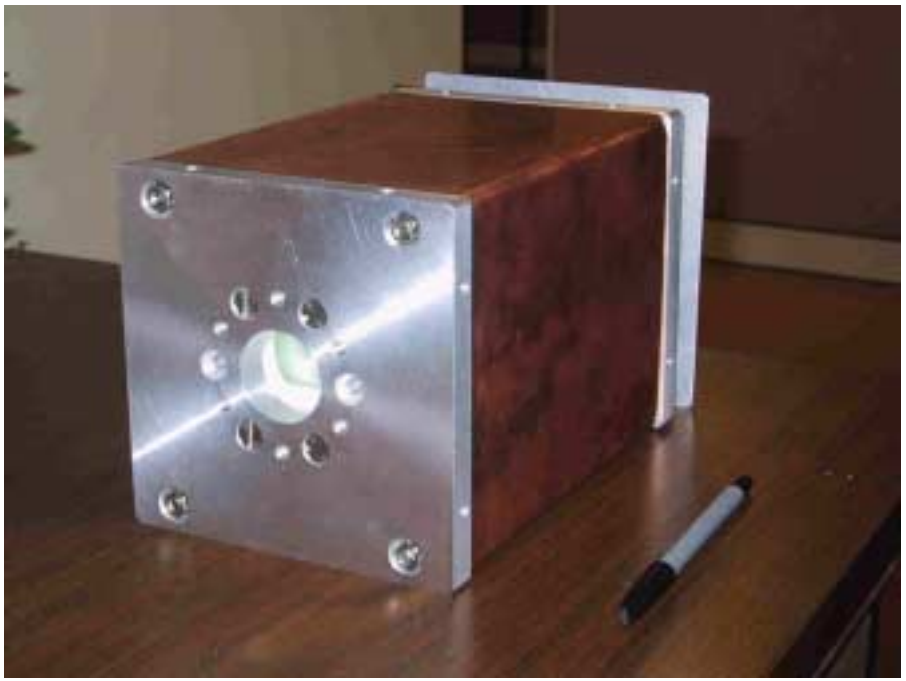
- plasma diagnostic Danilo Pacella - Frascati

- MPGD detector Ronaldo Bellazzini - Pisa

- data acquisition CAEN - Viareggio

- set-up FTU - Frascati

Next experimental campaign (Jan - June-2003)



New detector layout , compact, light, easy to be moved and shielded

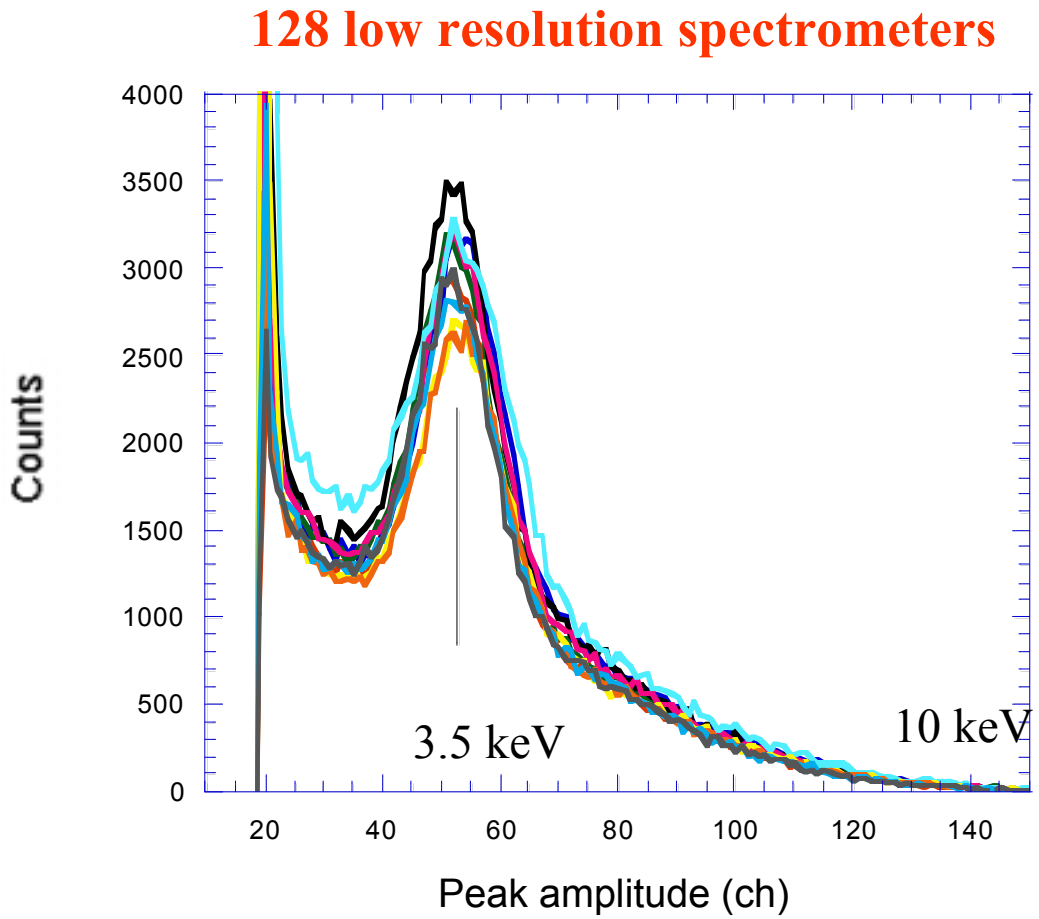
VME Crate (CPU, timer pulser, discriminators and Scalers for 128 channels)

amplifiers

NIM crate (High Voltage Power supplies)

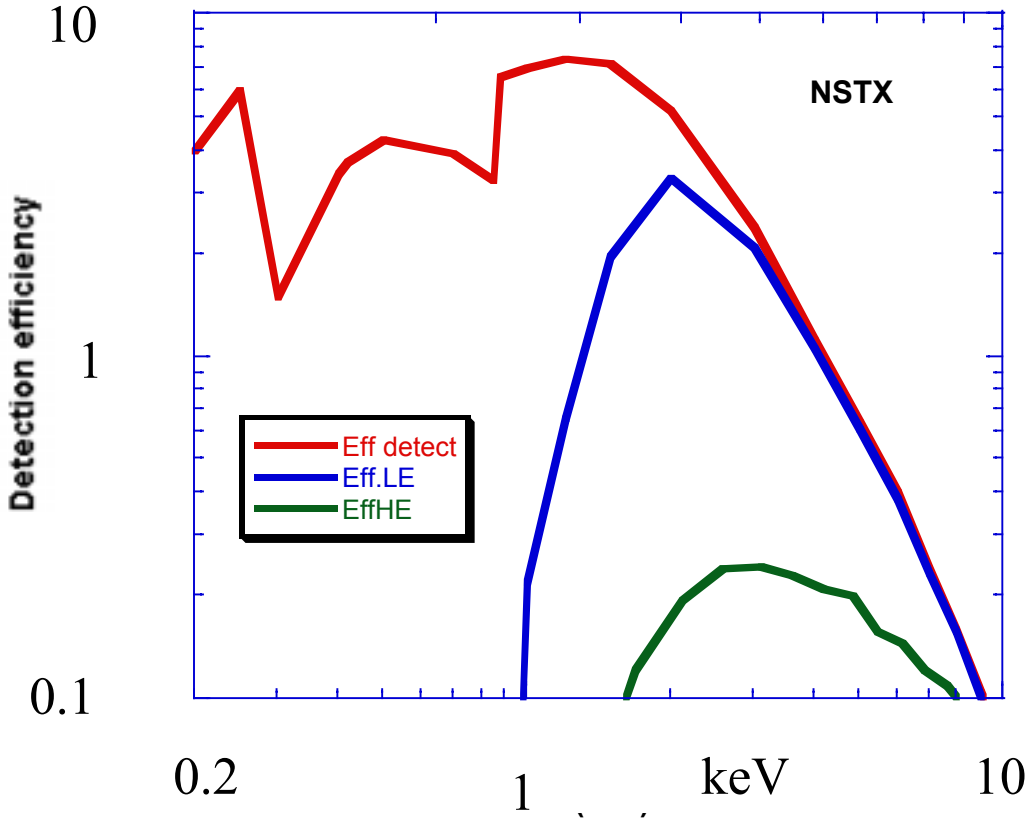
CD power supplies for Preamplifiers and amplifiers

All the pixels have the same spectral response (by 2%) as shown , with an X ray source of 1- 10 keV



Detection efficiency (Ne - DME) for three configurations

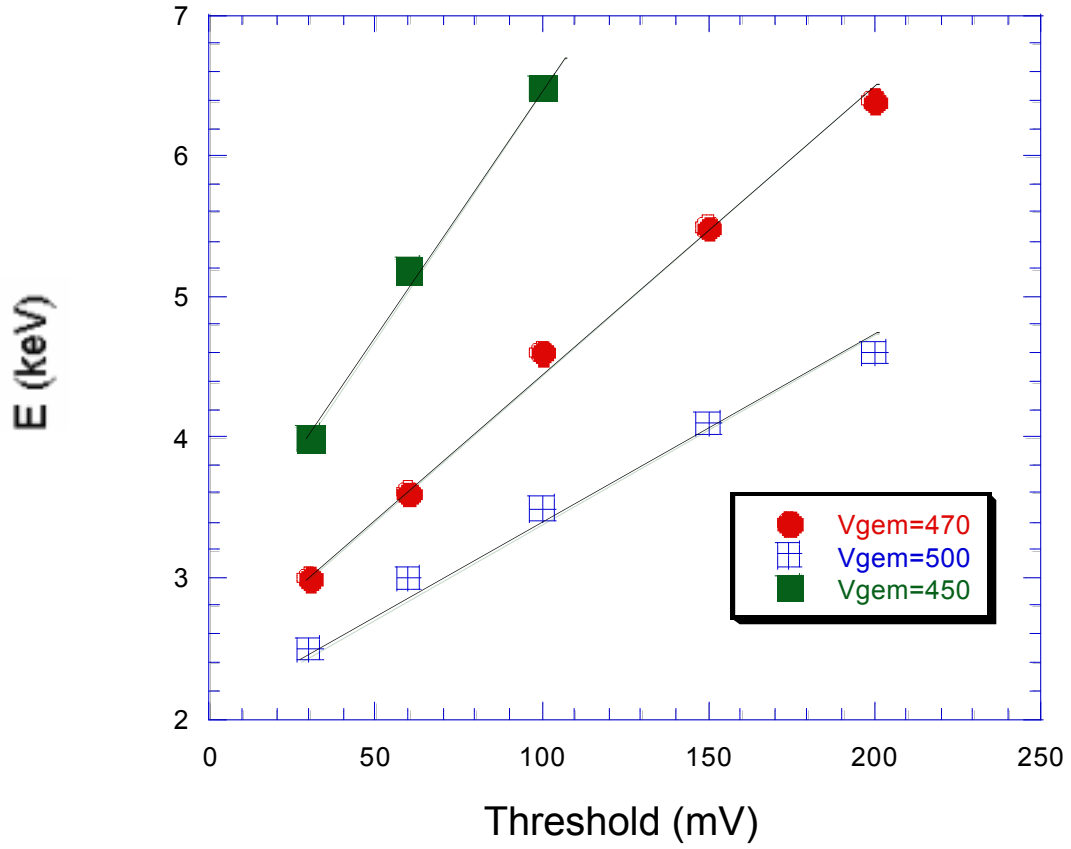
1) Detector (with ultrathin window)
2) Detector, thin (12 micron) Be window on the machine and He in between
3) Detector, thick (400 micron) Be window on the machine and air in between



Frascati 2001
Princeton 2002
2.5 - 8 keV

Princeton 2003
0.8 - 8 keV

Energy range can be preset changing the GEM voltage

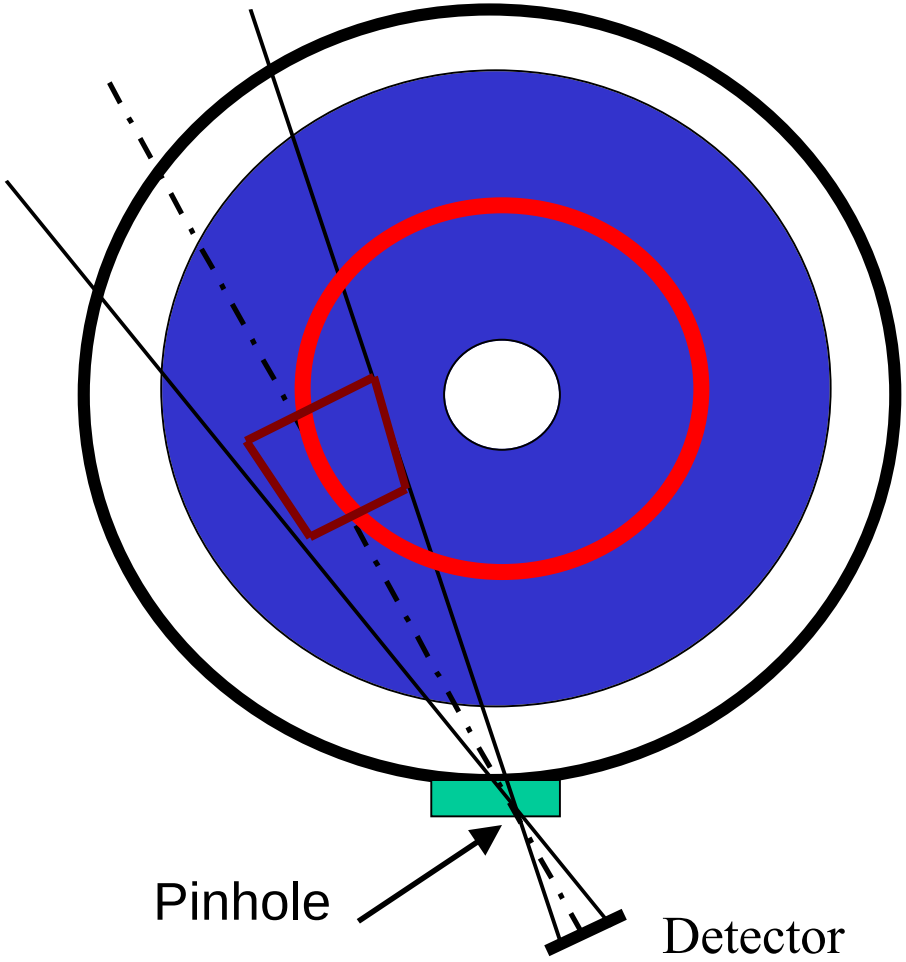


Ne = 80%

DME = 20 %

3- D source (plasma), whose depth is comparable with the ‘focal length’

Tangential view

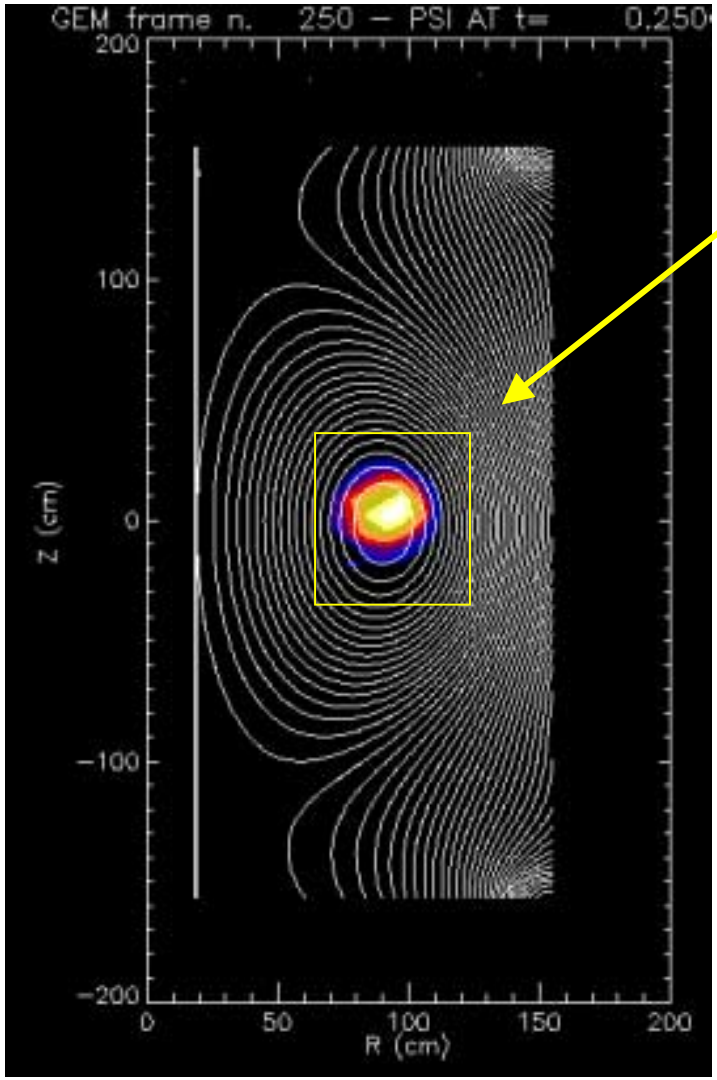


NSTX

Imaging capability
+
Energy discrimination

Tune up on the X-ray energy
of the emitting zone of interest

Centered wide view



View of the X-ray pin-hole camera

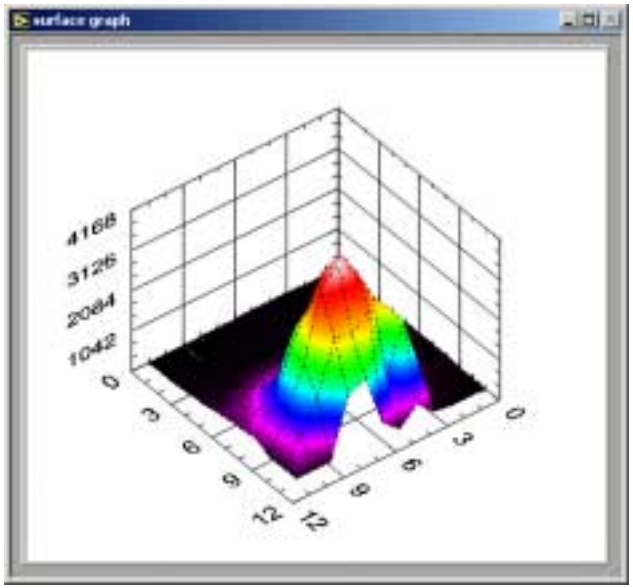
Image on plasma 80 cm*80 cm

Photon counting mode

Energy range 3 - 8 keV

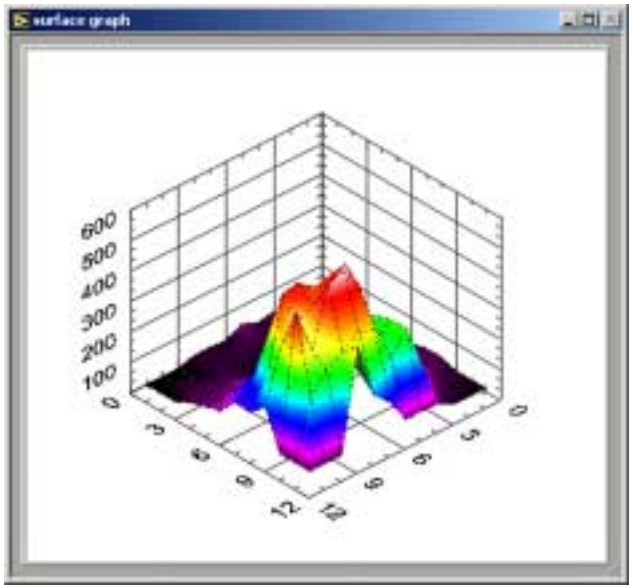
Spectral analysis confirms that photons are "thermal"

Max =4200



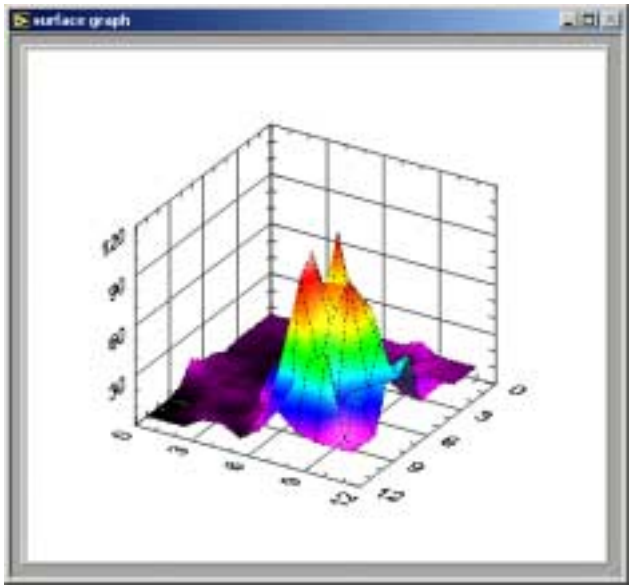
3 - 8 keV

Max=500



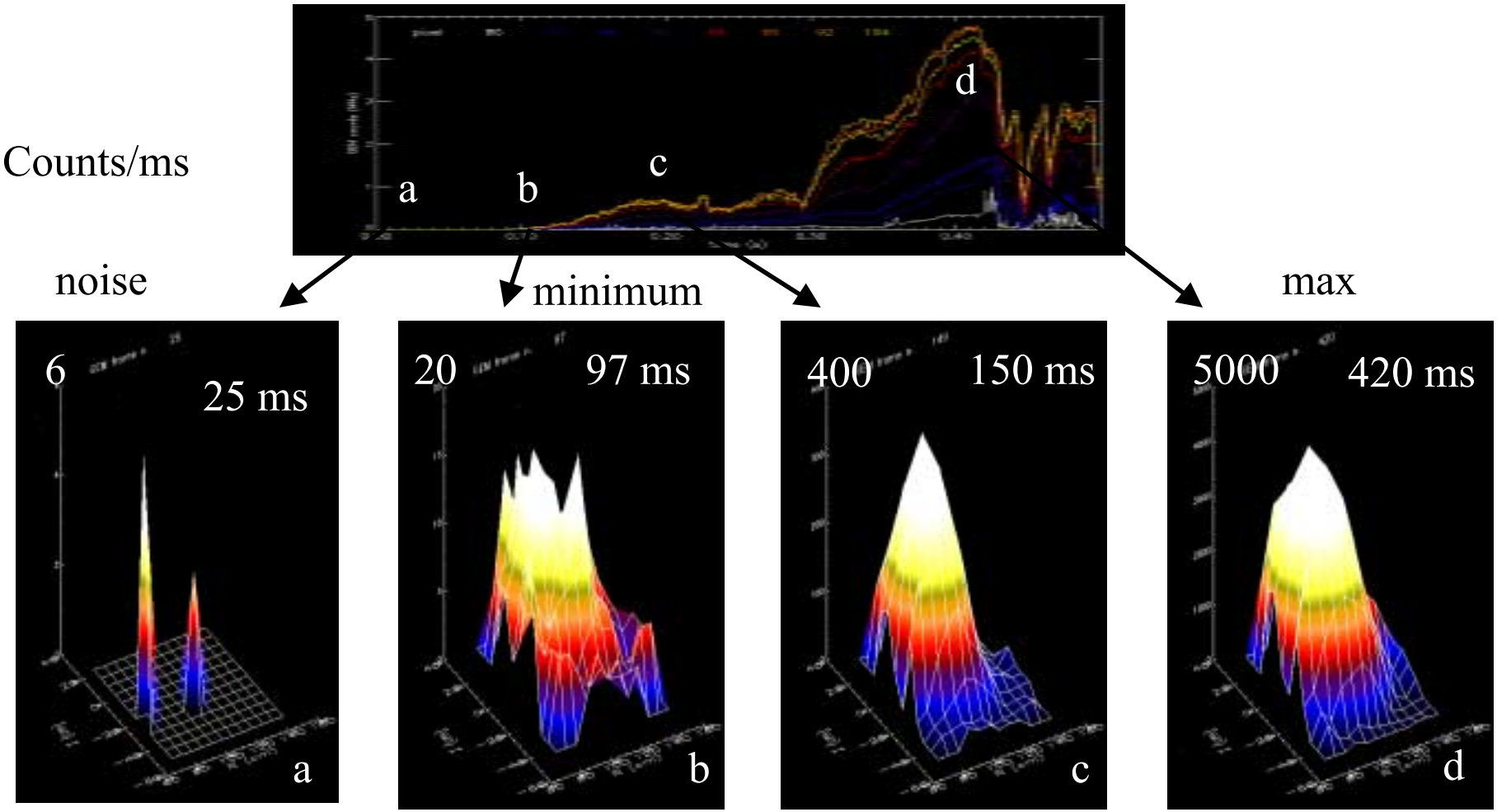
4 - 8 keV

Max=90



5 - 8 keV

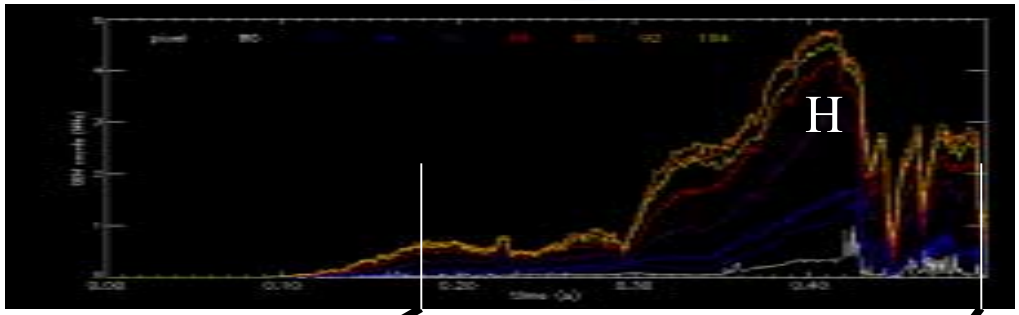
High Dynamic Range

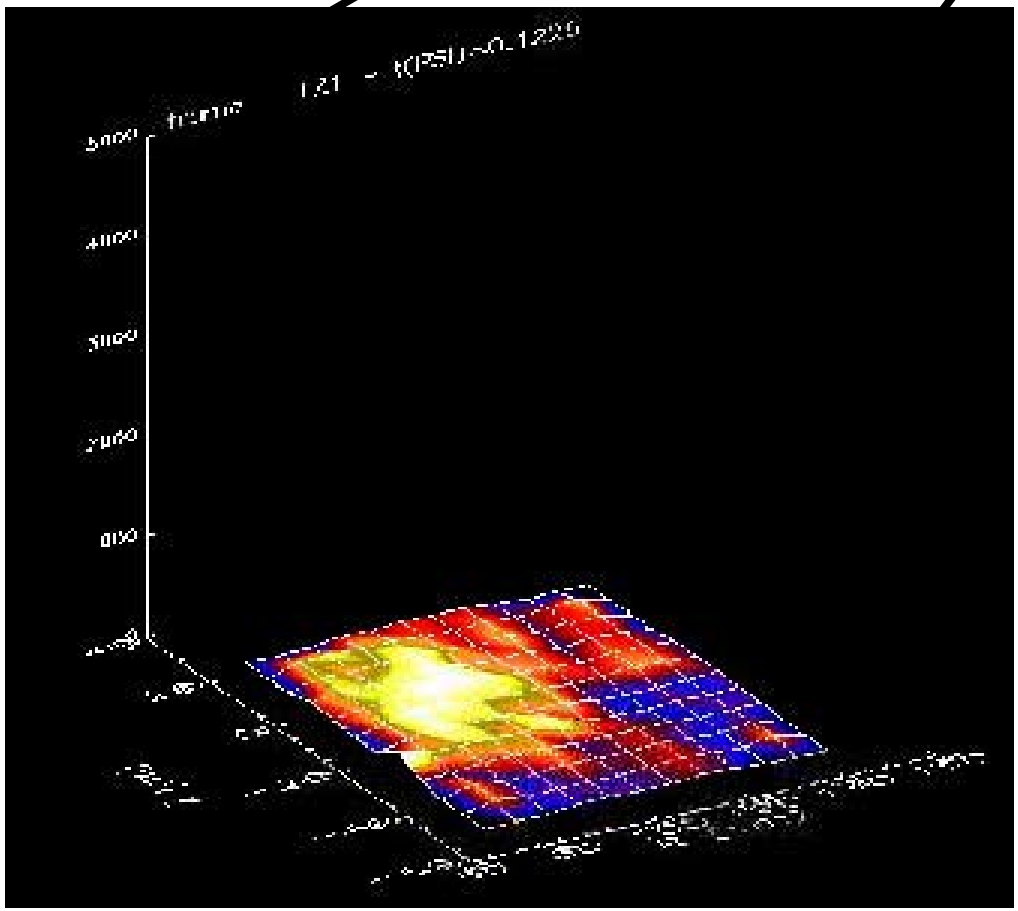


Signal / noise = 1000

Effective dynamic range = 300

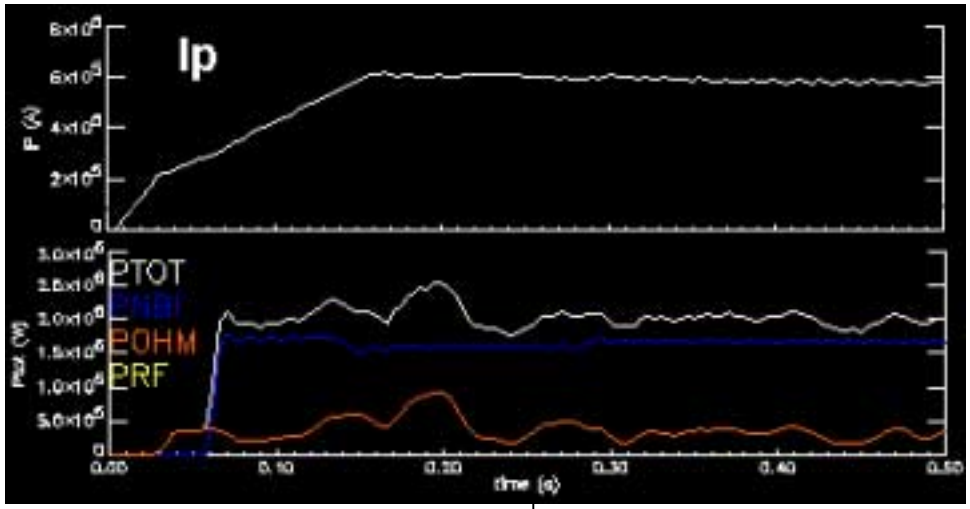
H- MODE

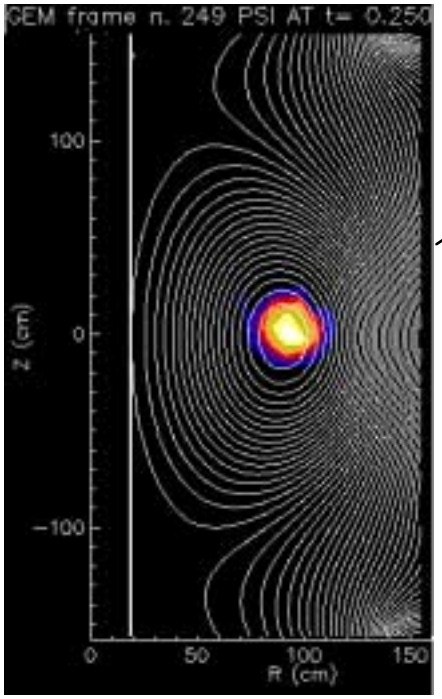


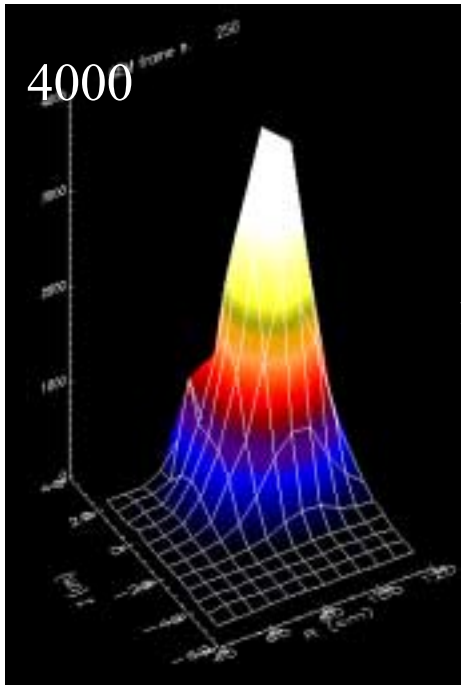


 # 107314

Click for animation





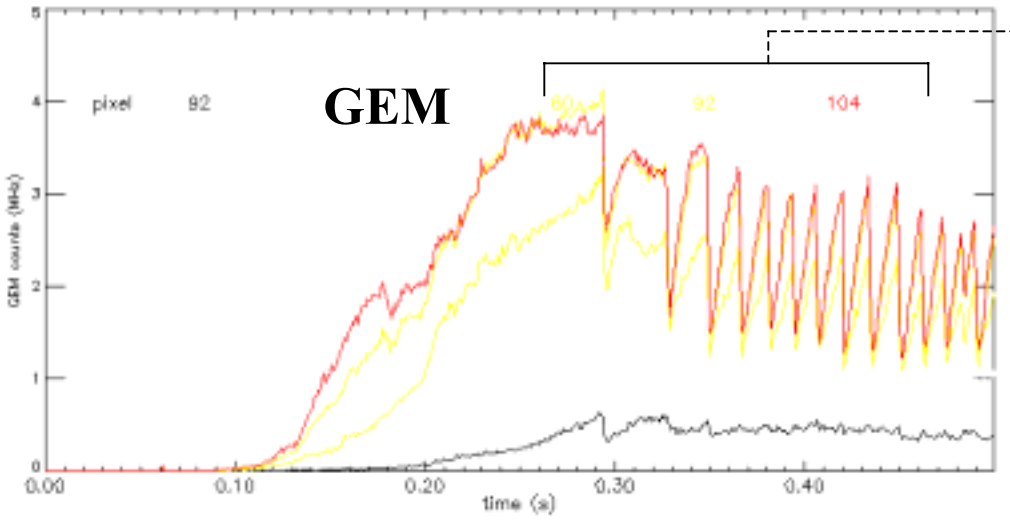


 # 107352

L - MODE

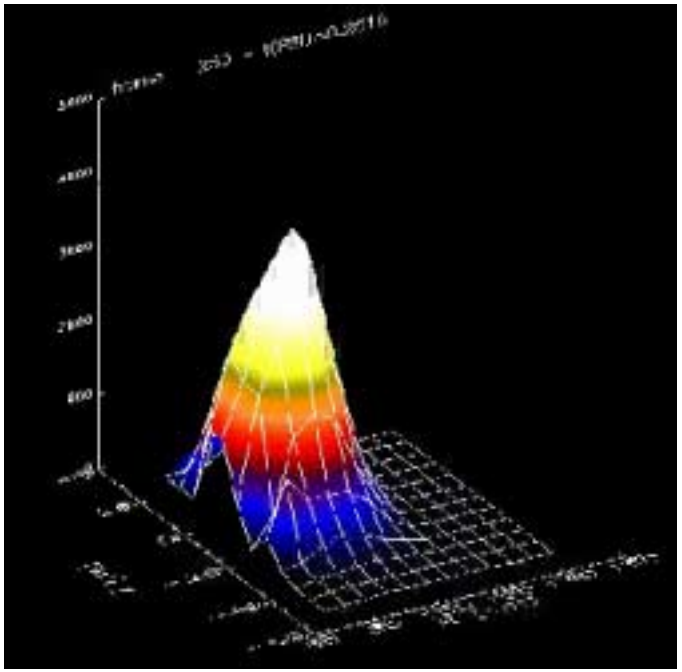
I_p = 0.6 MA
frequency = 1 kHz)
strongly peaked
emissivity during
P_{NBI} = 1.6 MW
L-mode plasma

Sawtooth activity

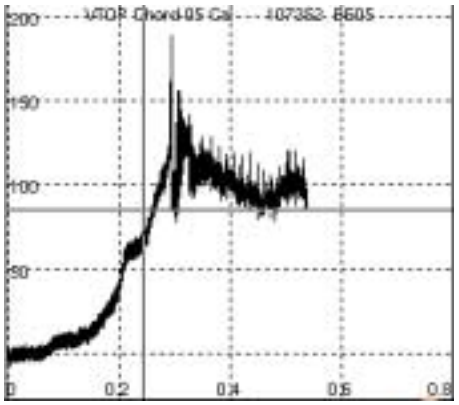


107352

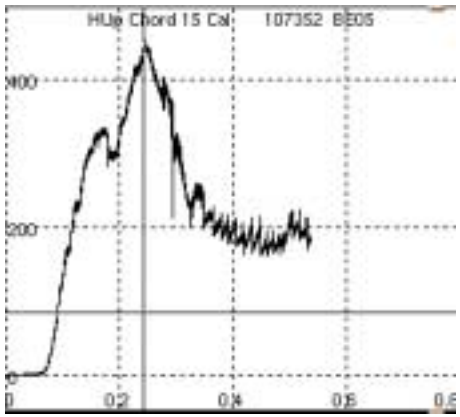
Click for animation



USXR_VTOP

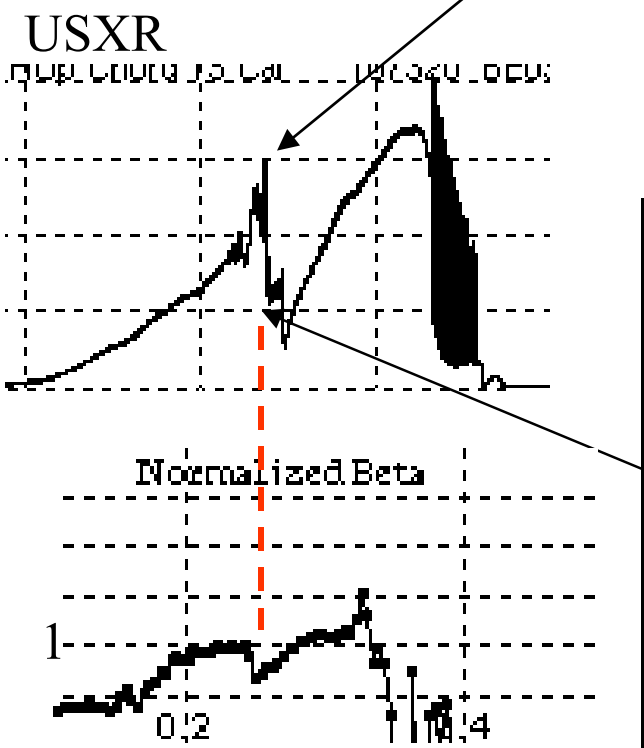


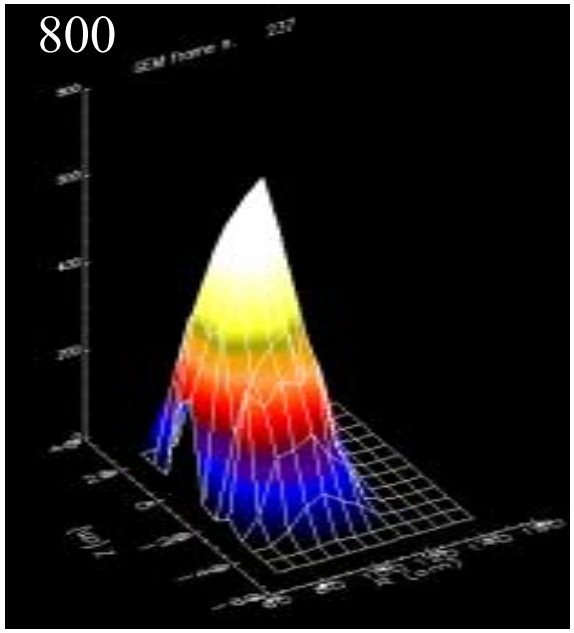
USXR_HUP

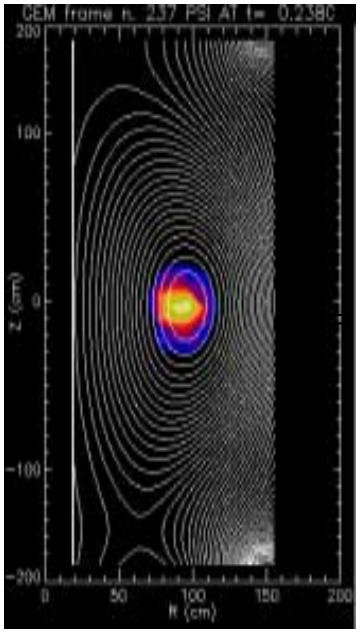


IRE

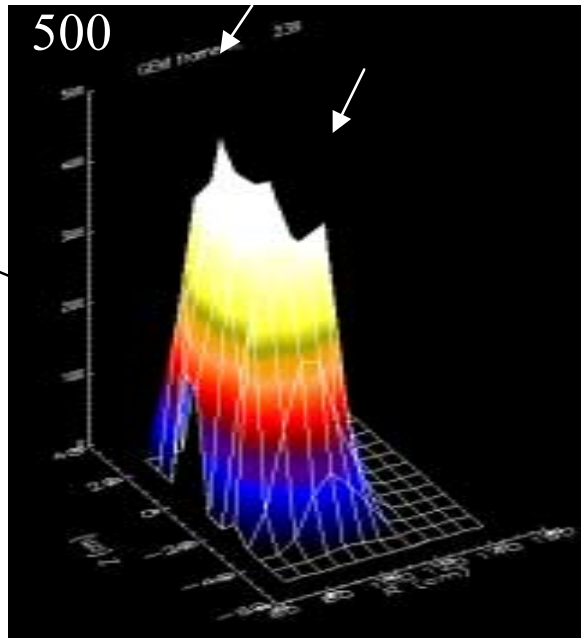
 # 107320
(ohmic, $I_p \sim 1$ MA) in current plateau

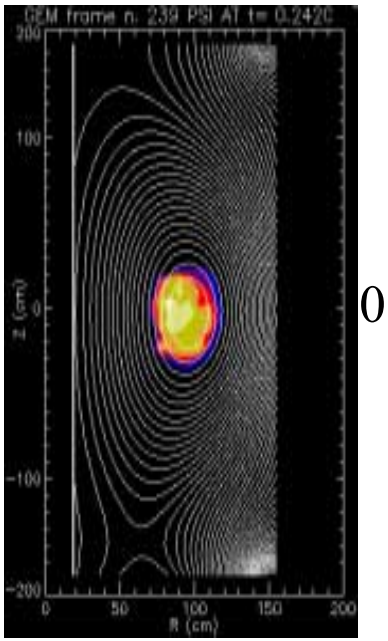






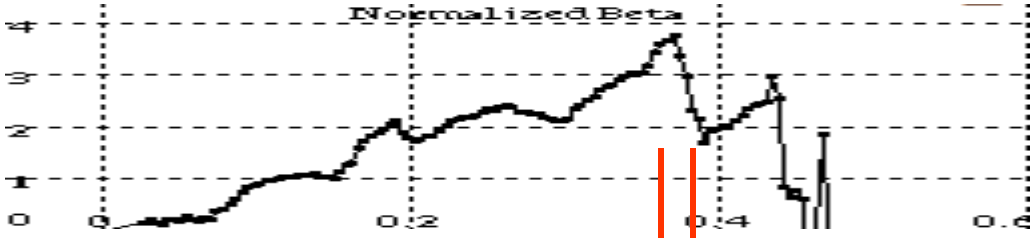
0.237 ms



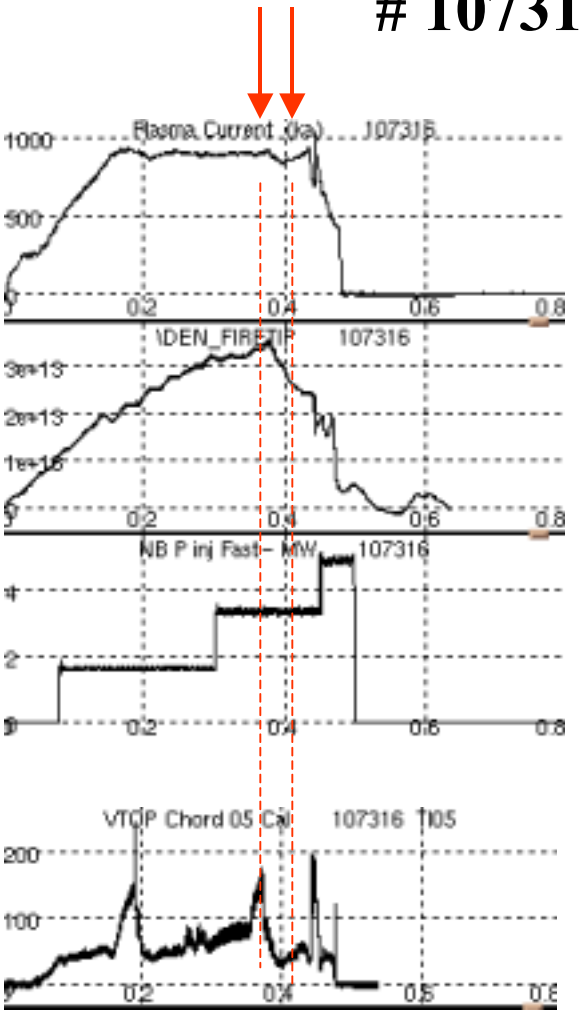


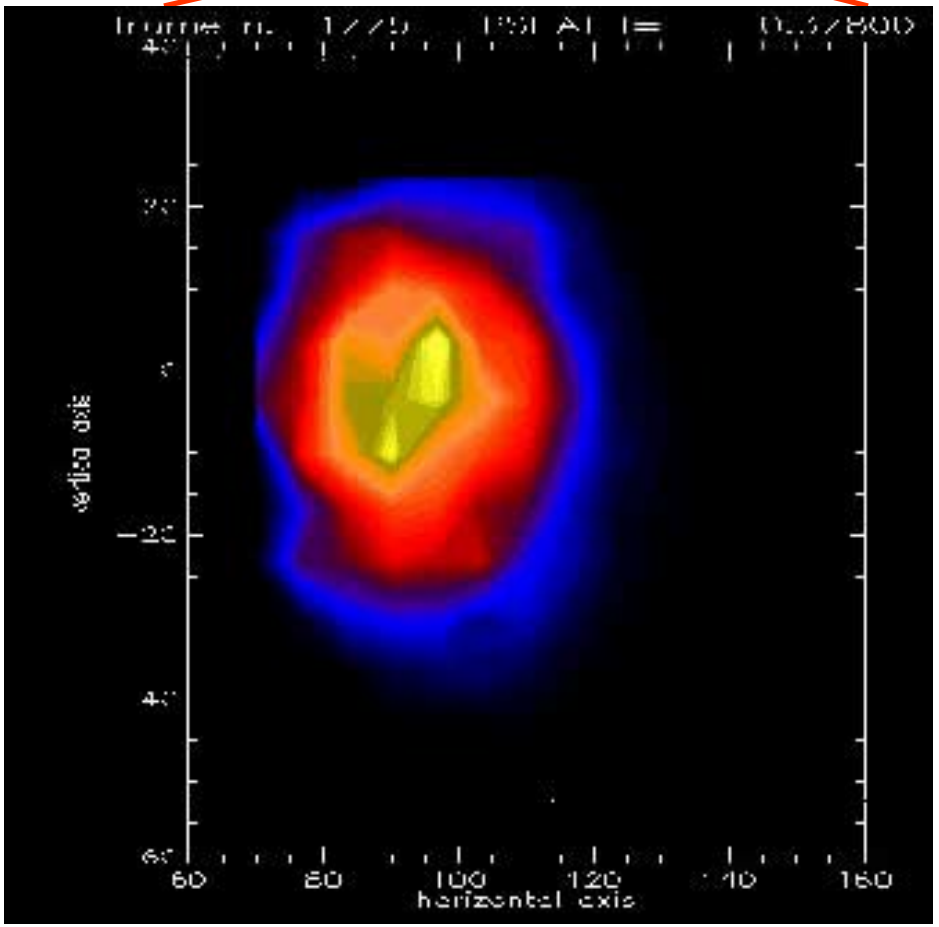
0.239 ms

MHD modes



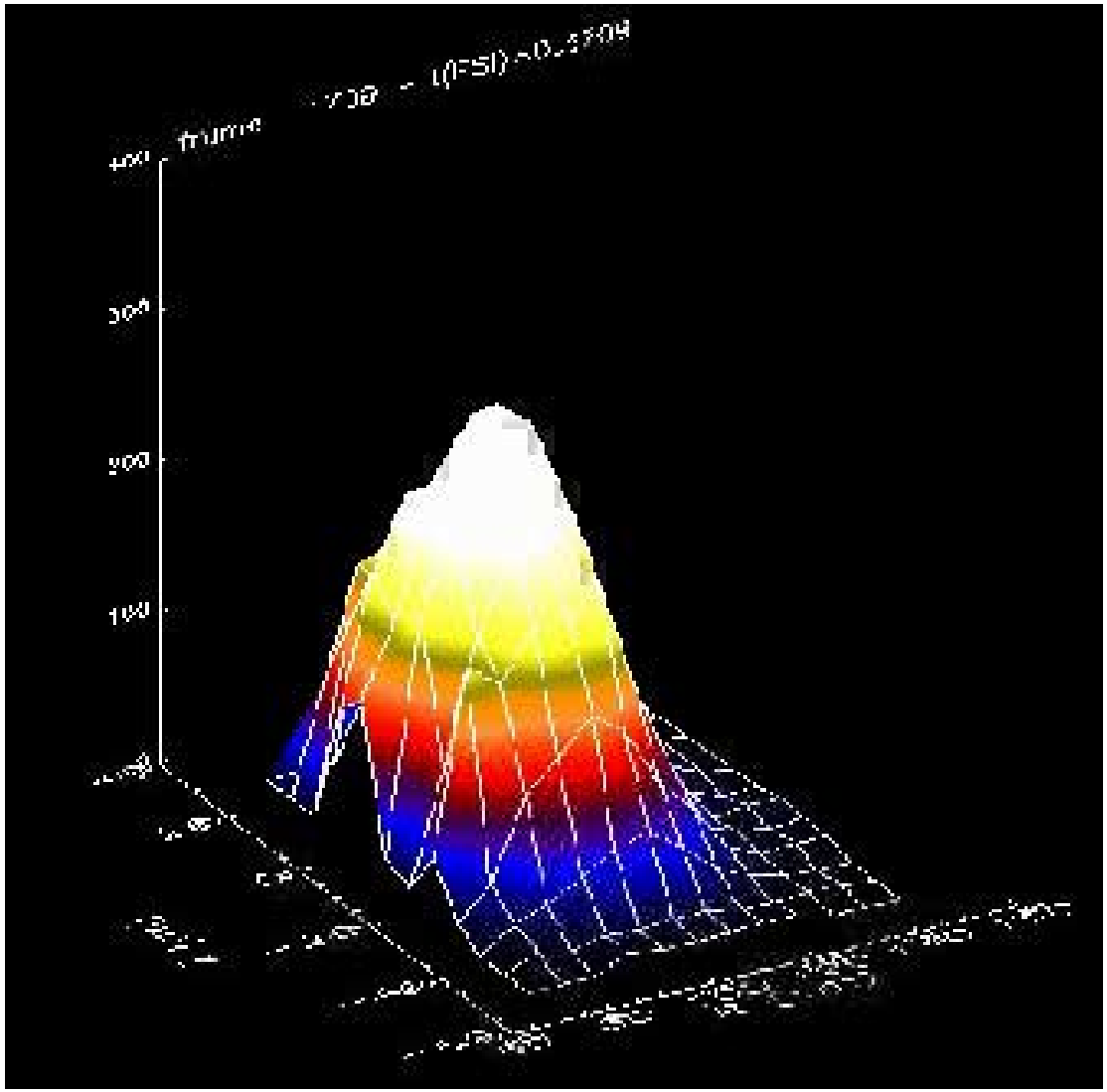
 # 107316





10 khz

Click for animation



MHD modes

 # 107316

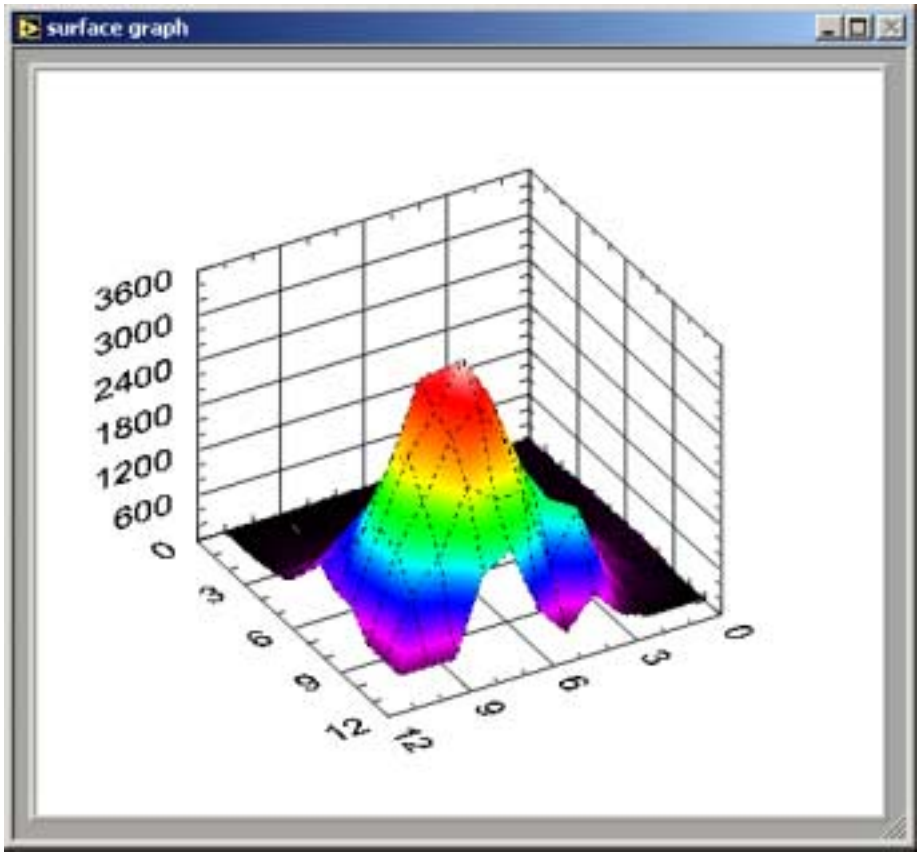
Sampling: 10 khz

Click for animation

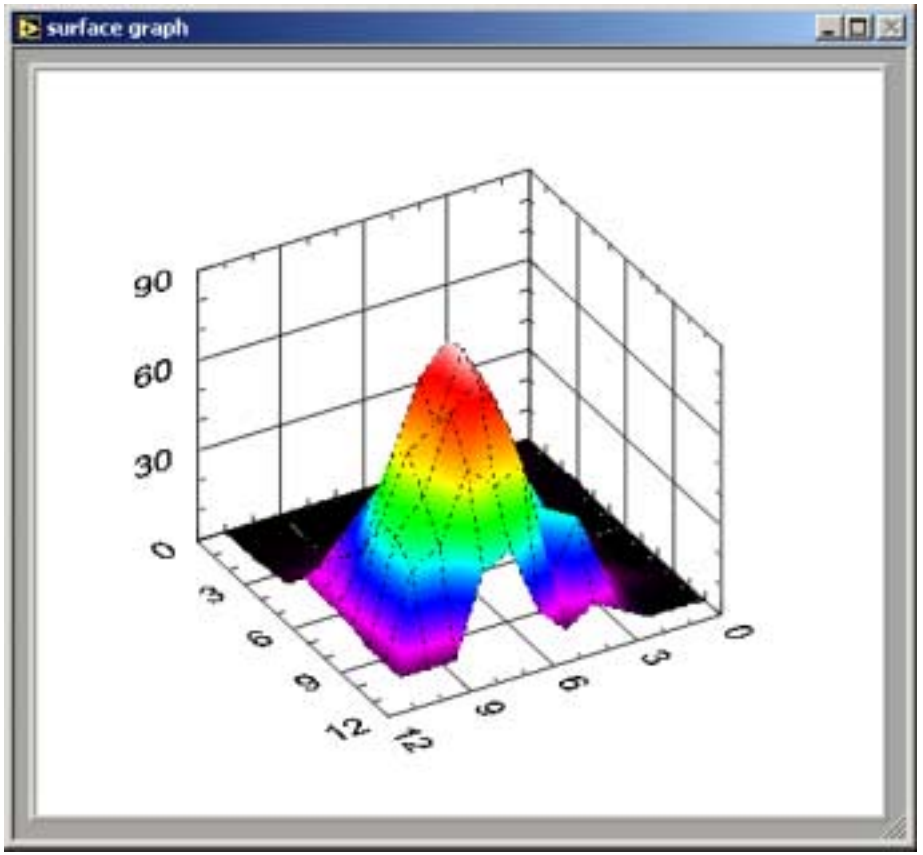
Sampling at 50 kHz

 # 107356

t = 298 ms 1 Khz



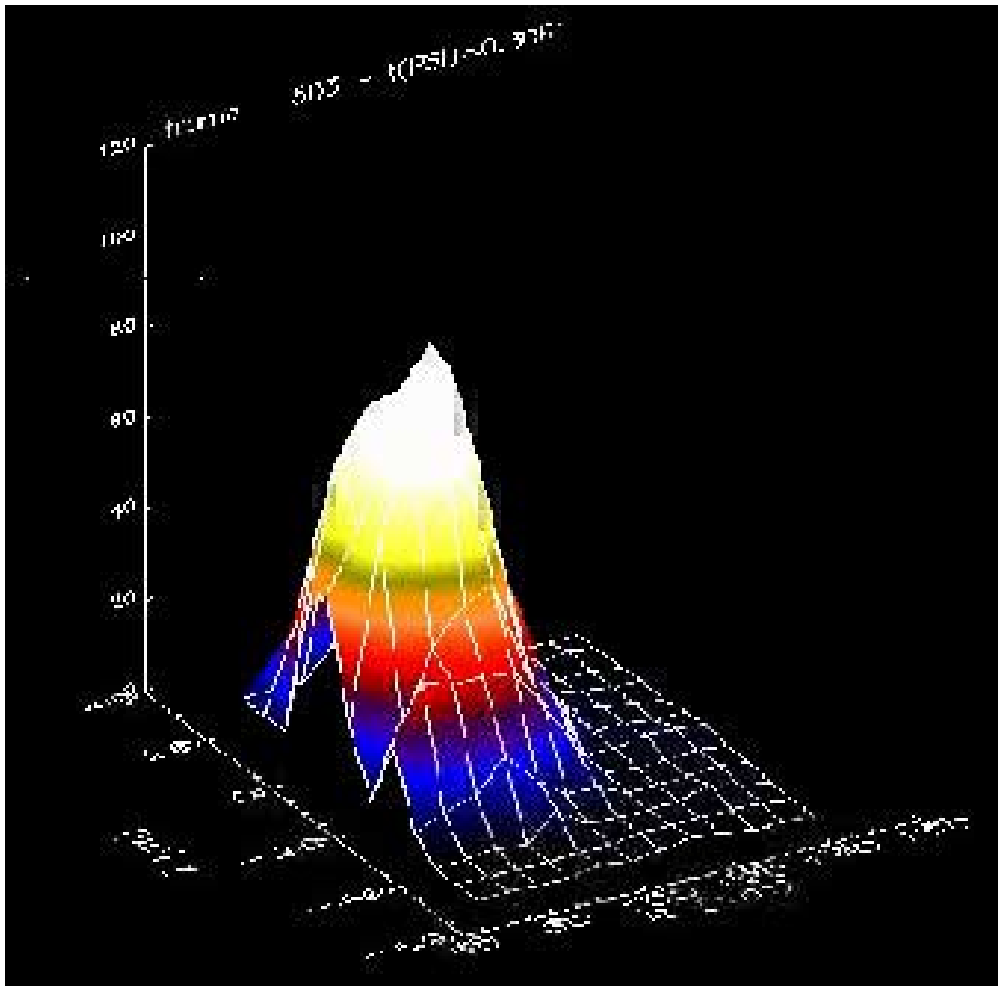
t = 301 ms 50 kHz



 # 107356

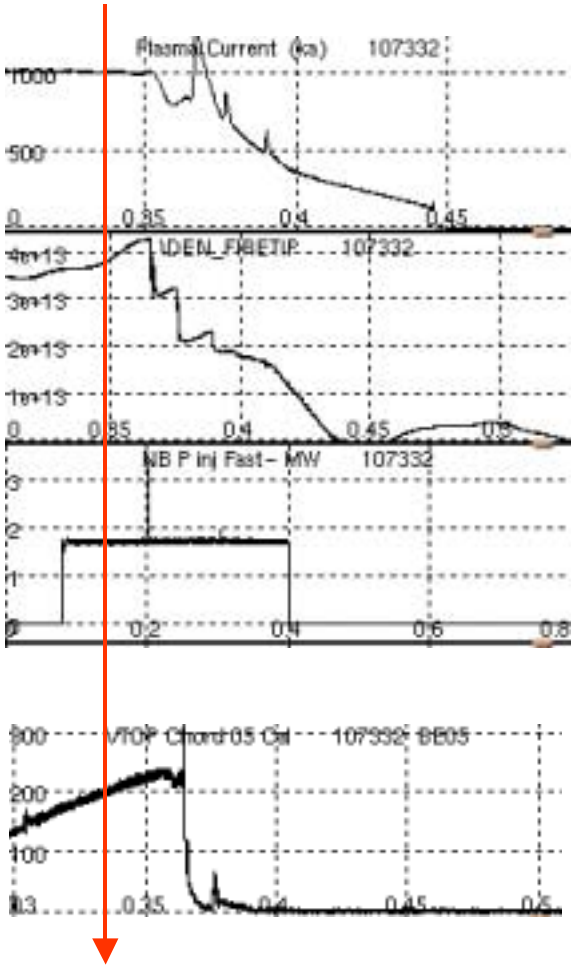
50 khz

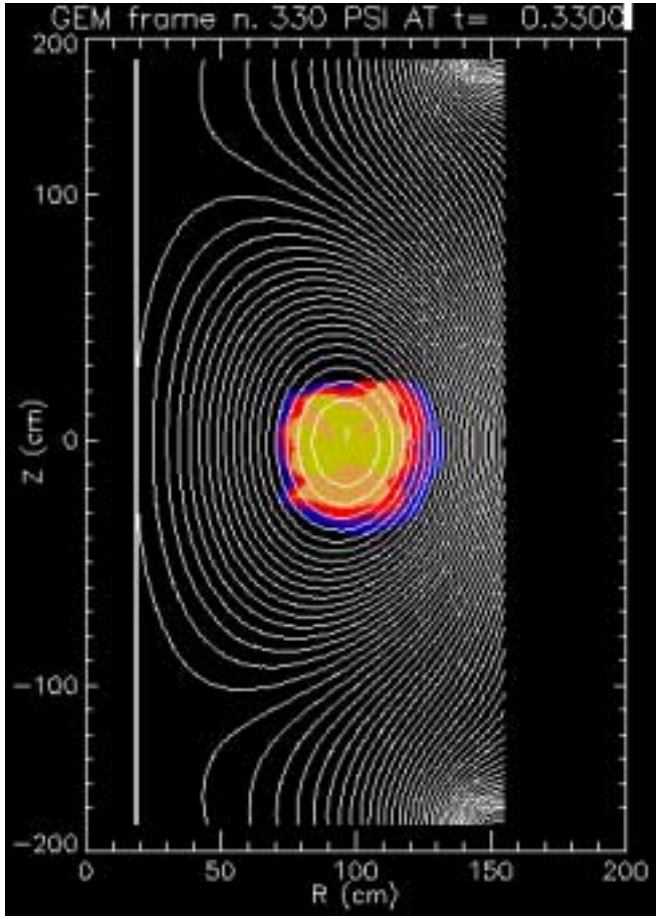
Click for animation



107332

$I_p \sim 1$ MA, $P_{NBI} = 2.0$ MW t = 0.33 s H-mode





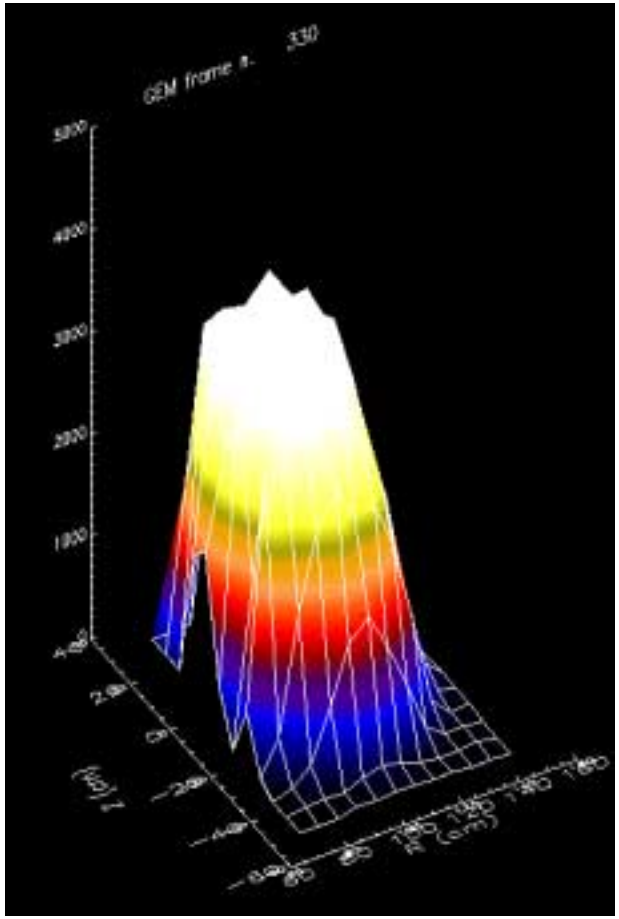
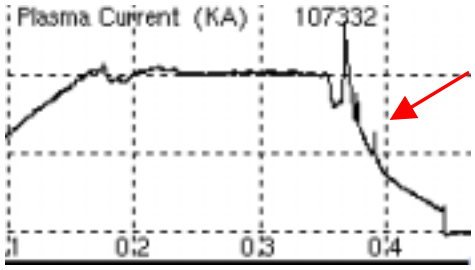
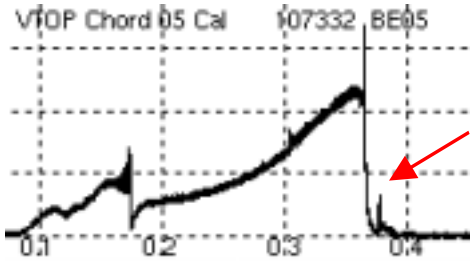
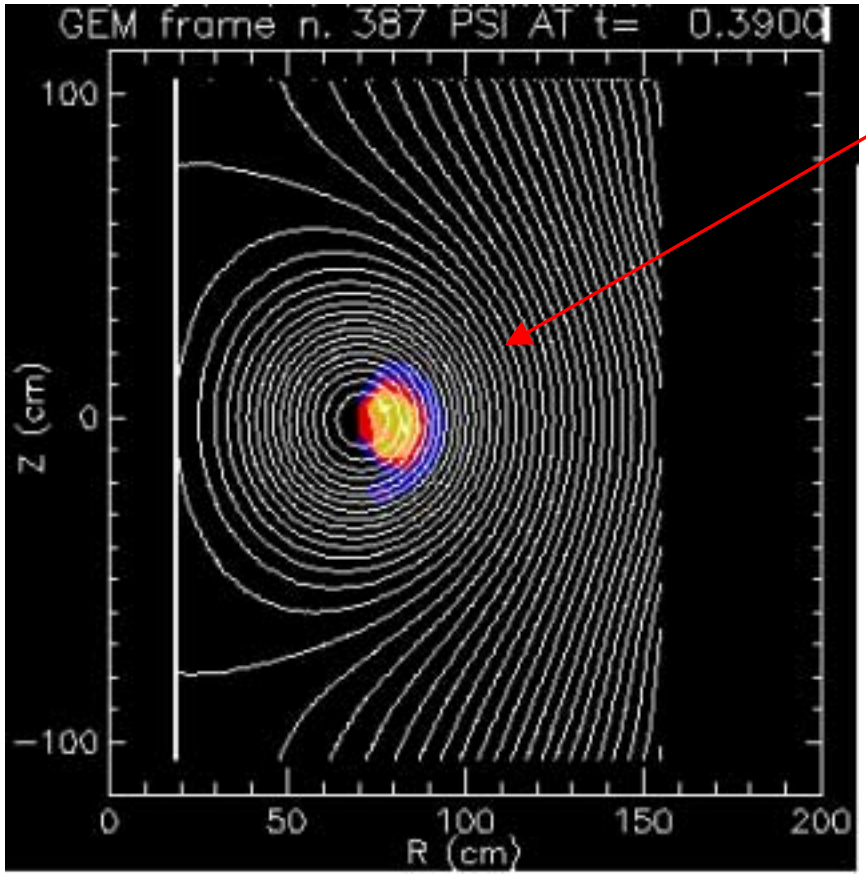


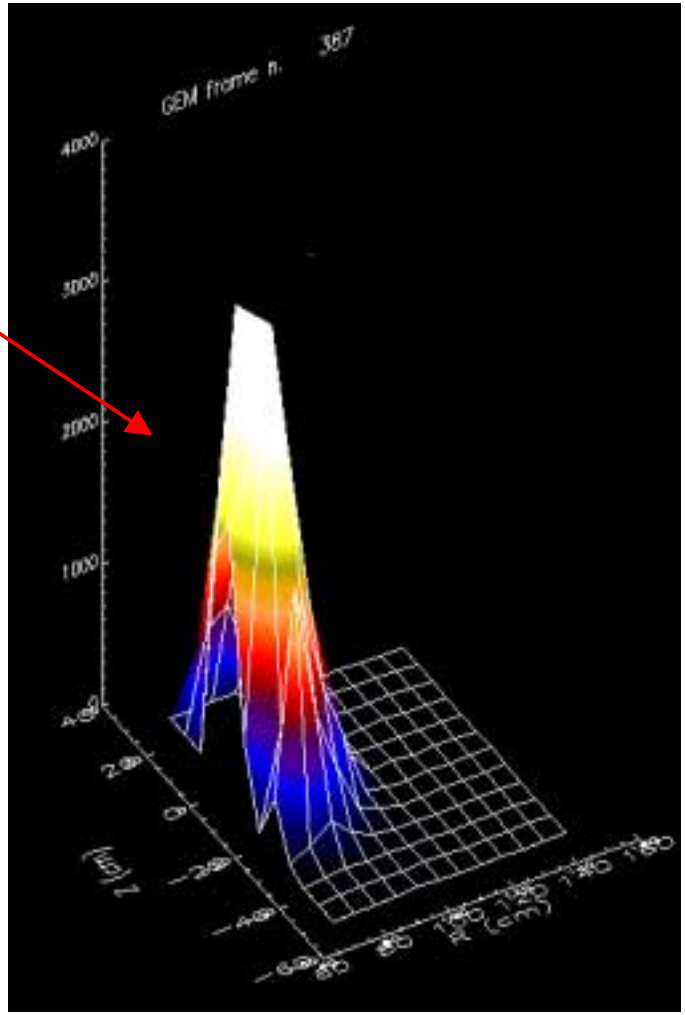
IMAGE REPRODUCE THE CURVATURE OF THE MAGNETIC SURFACES



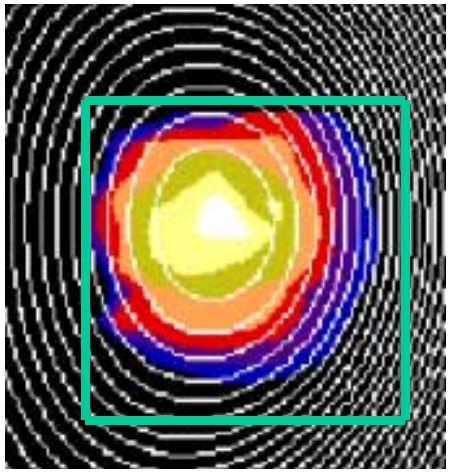


Sh 7332

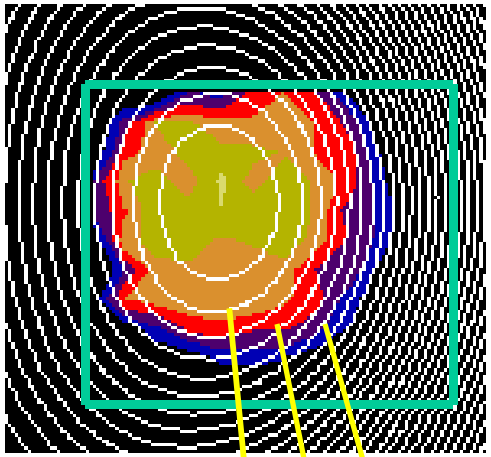




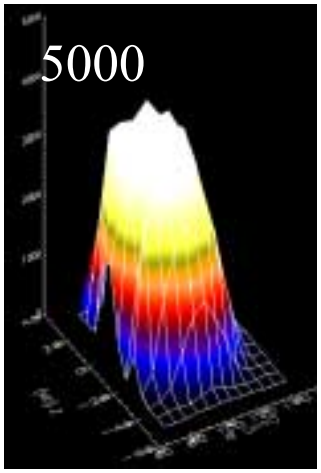
ARE THESE SPATIAL MODULATIONS REAL ?



280 ms



330 ms



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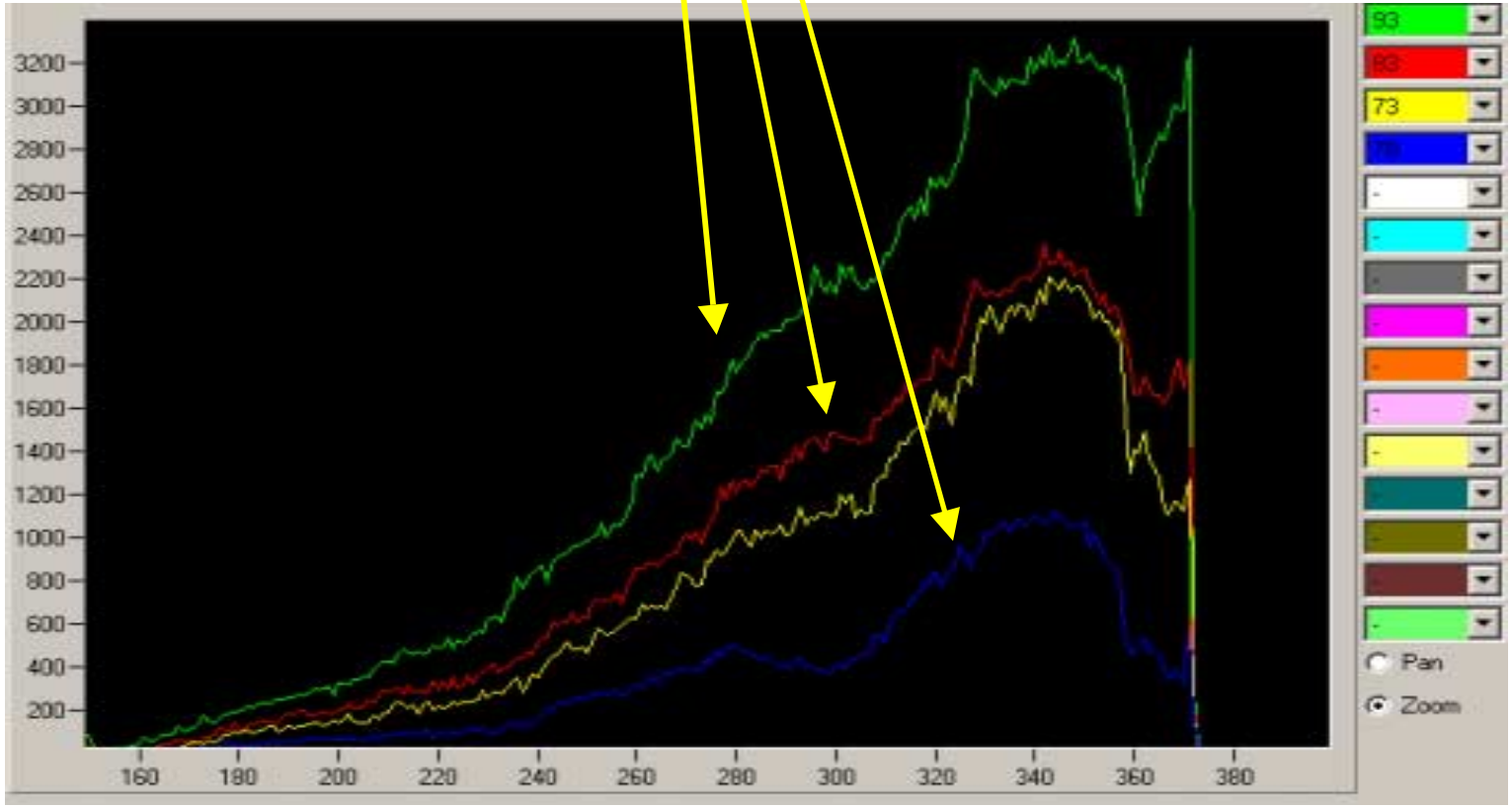
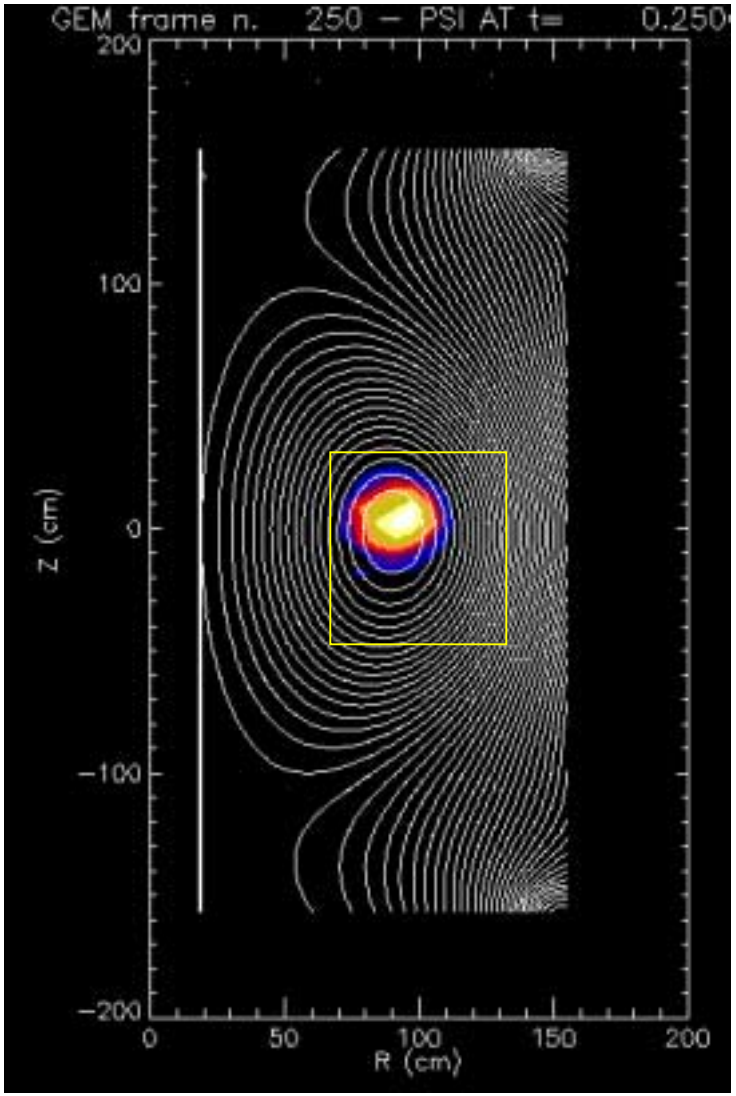
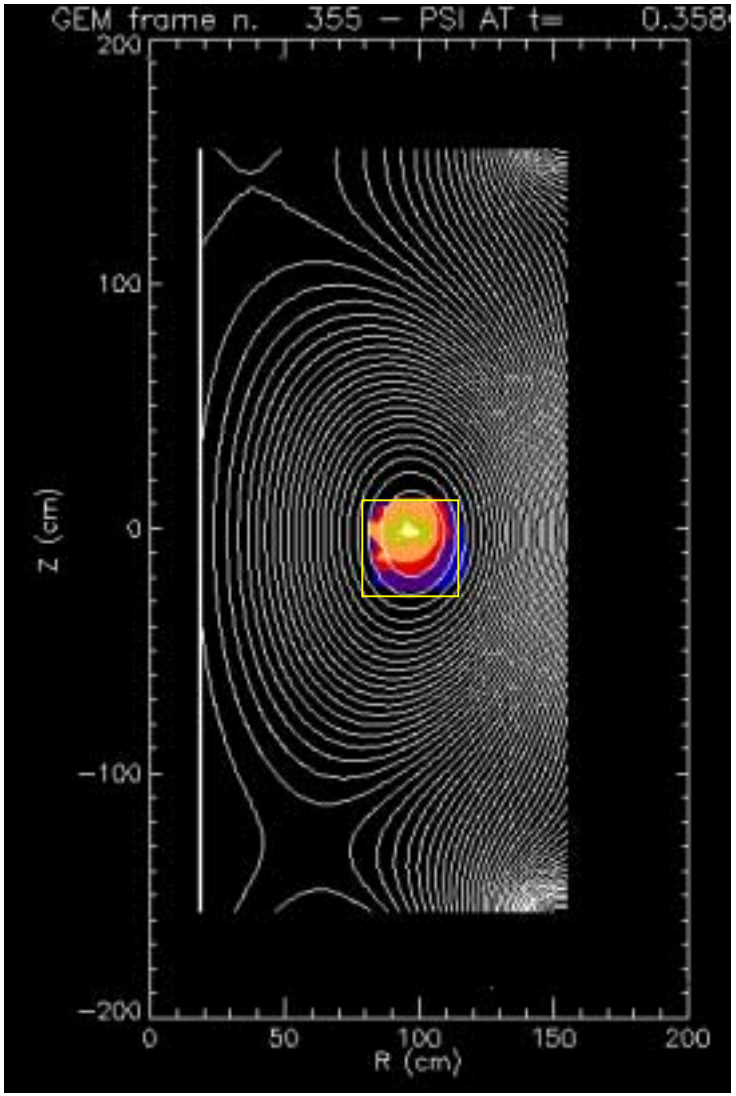


IT IS A PINHOLE CAMERA : ZOOM ON THE CORE !

View 1

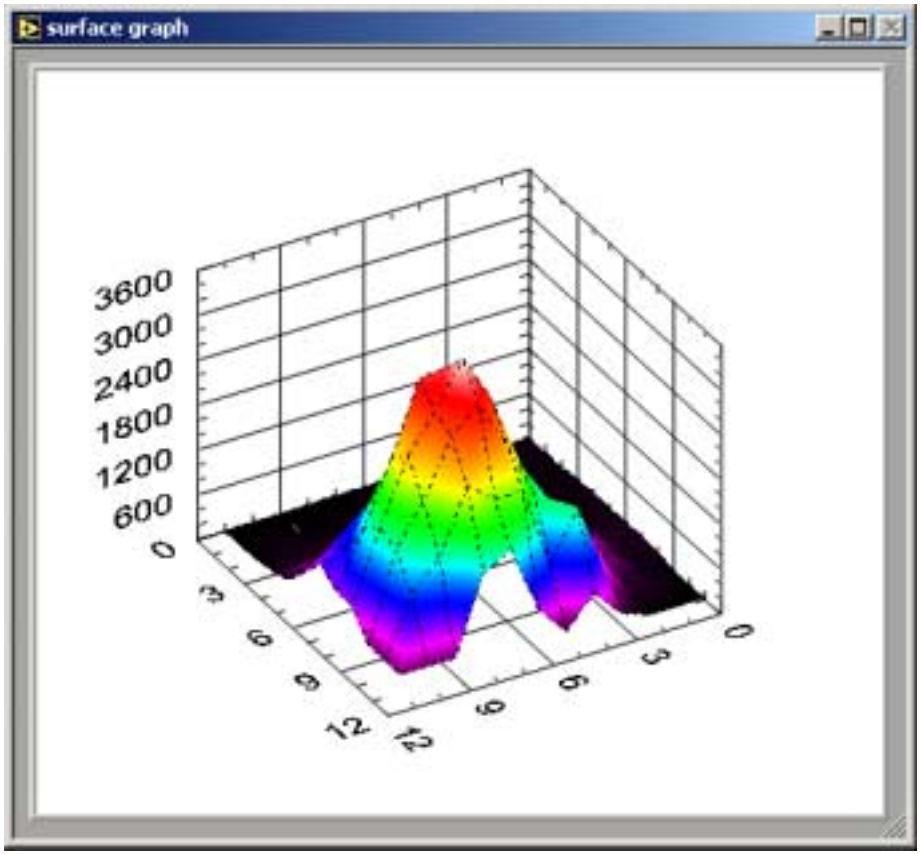


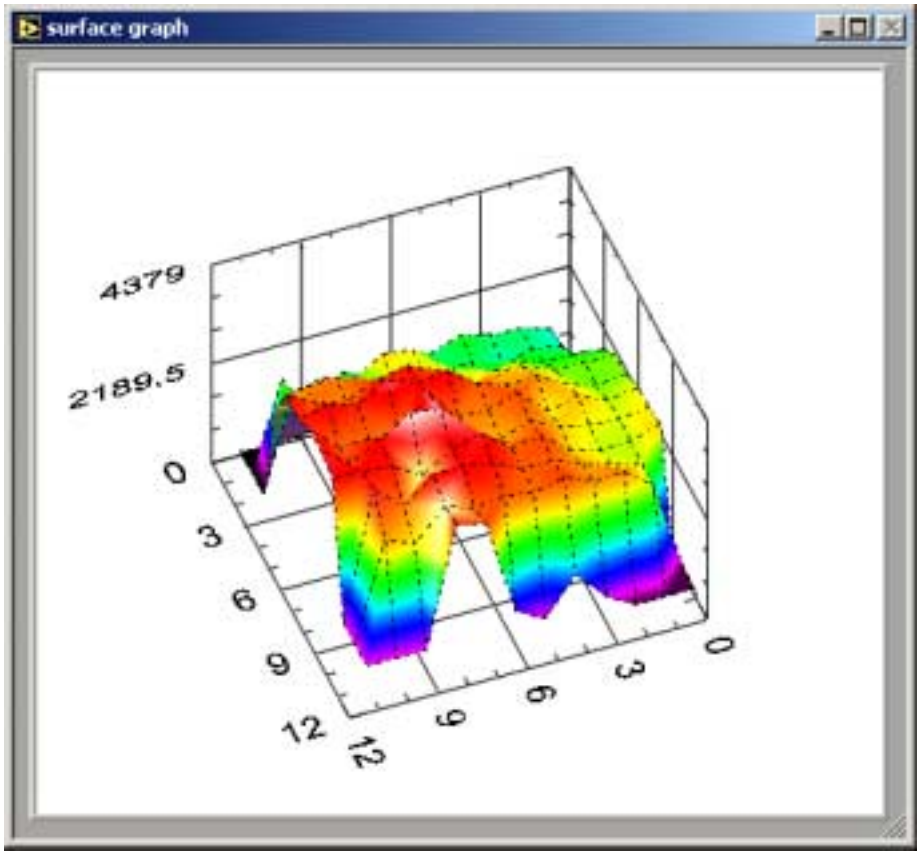
View 2



View 1

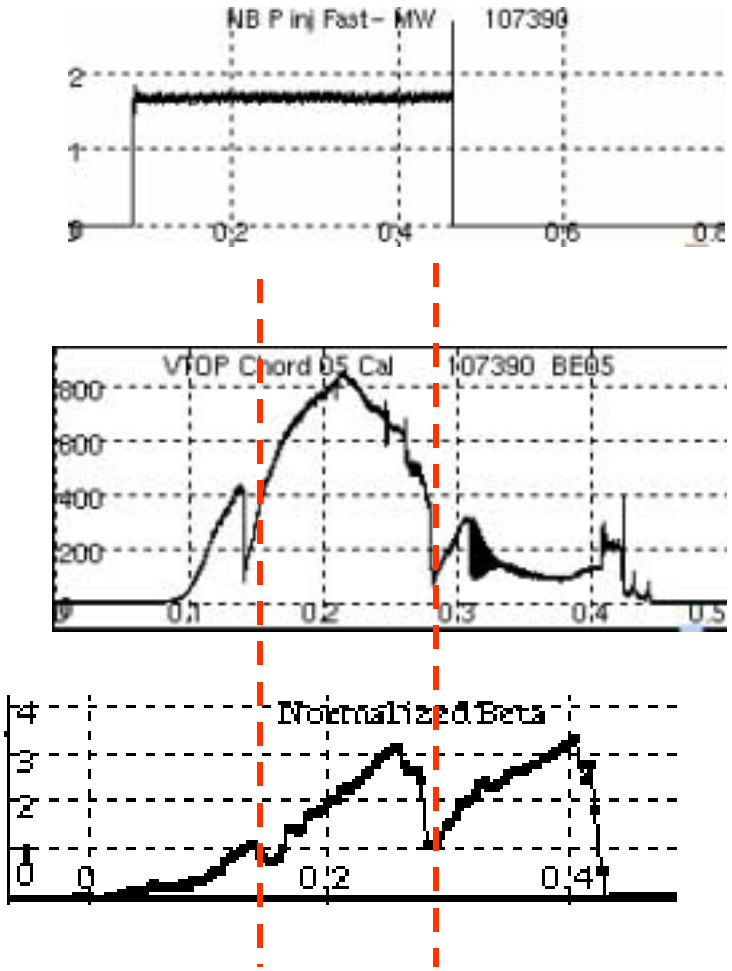
View 2

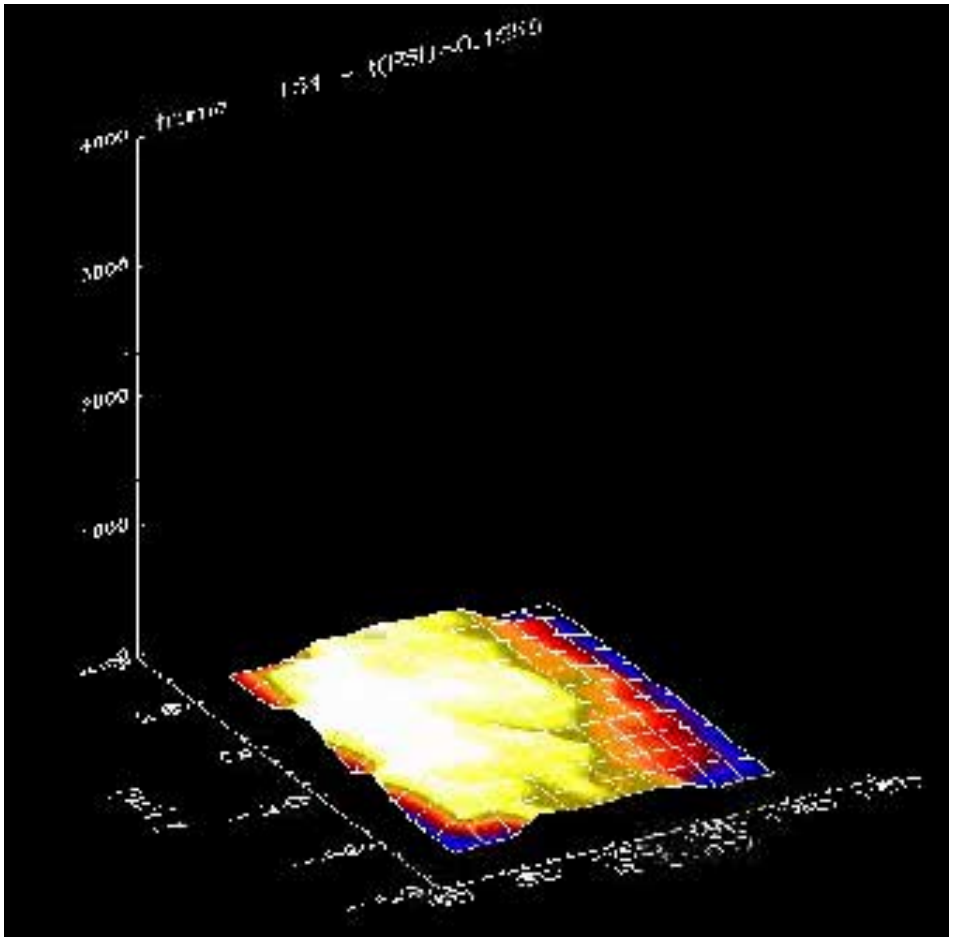

surface graph
3600
3000
2400
1800
1200
600
0
3
6
9
12
12
6
6
3
0


surface graph
4379
2189.5
0
3
6
9
12
12
6
9
3
0

107390

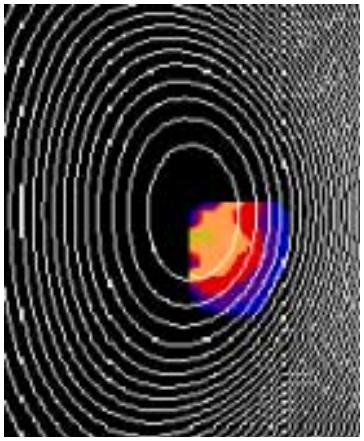
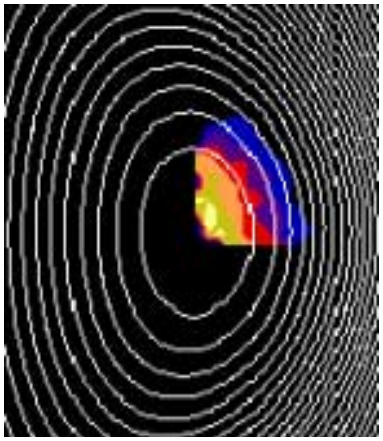
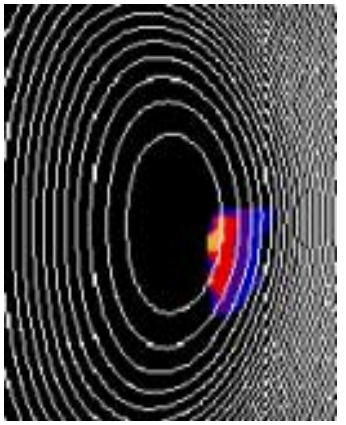
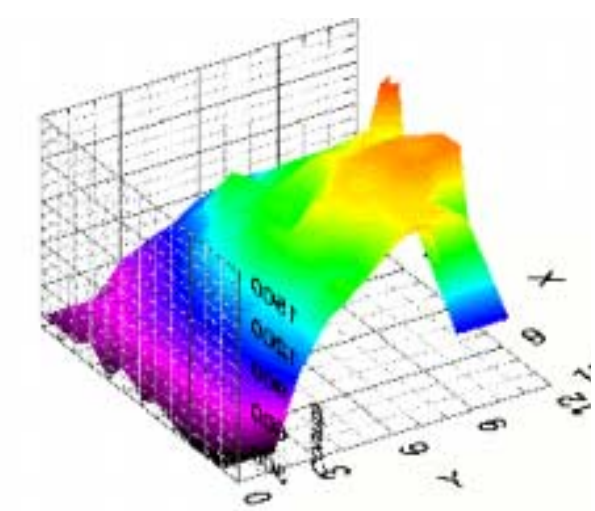
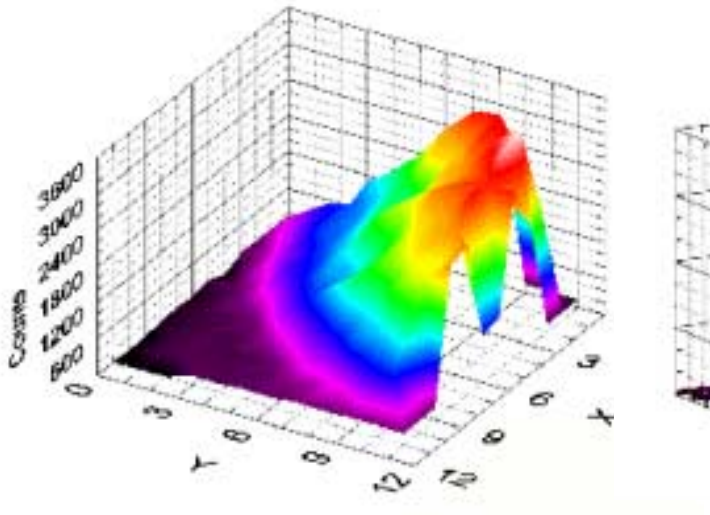
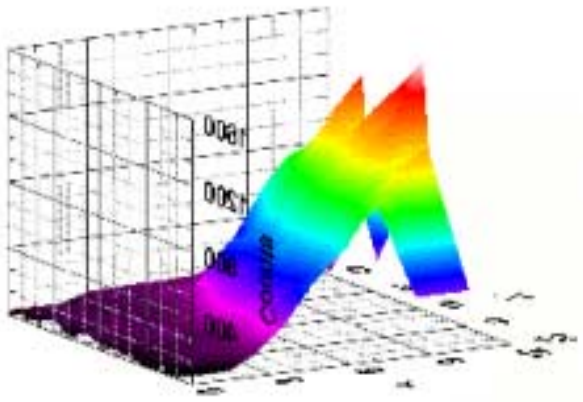
Sampling rate 1 kHz





Click for animation

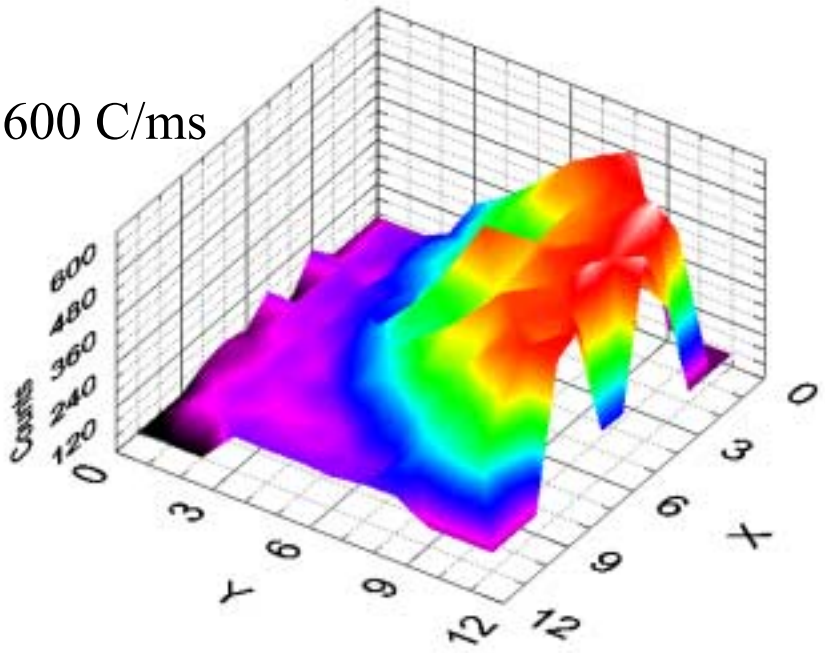
Images off axis

Distance pinhole- detector filled with He for lower energy

8 cm air 3-8 keV

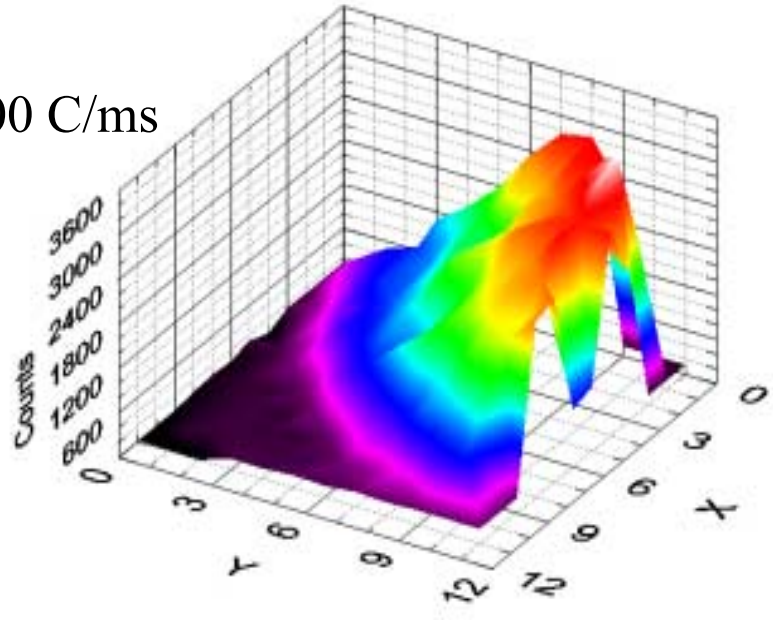
600 C/ms



108670

8 cm filled with He 2-8 keV

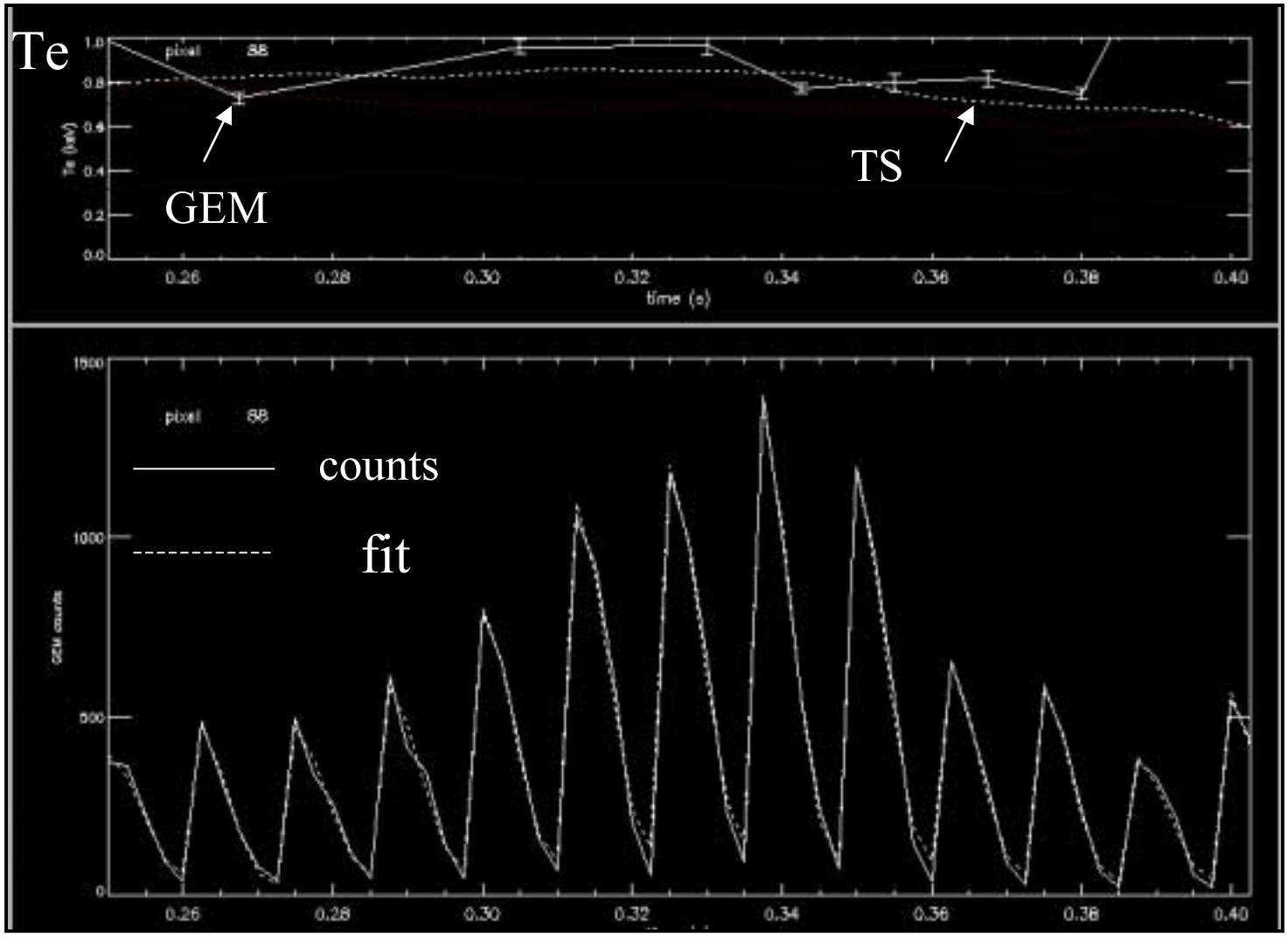
3600 C/ms



108729

Threshold scan (5) and temperature assessment for one central pixel

Time/scan = 10 ms



5 energy intervals

3-8 keV
3.5-8 keV
4.3-8 keV
5-8 keV
6-8 keV

Fast X-ray imaging of the NSTX plasma with a Micro Pattern Gas Detector based on GEM amplifier

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Submitted to the 14th APS Conference of High Temperature Plasma Diagnostics

Contribution of the MPGD X-ray camera

- Fast core MHD
- Perturbative transport
- 2D map of electron temperature
- RF Heating effects (?)

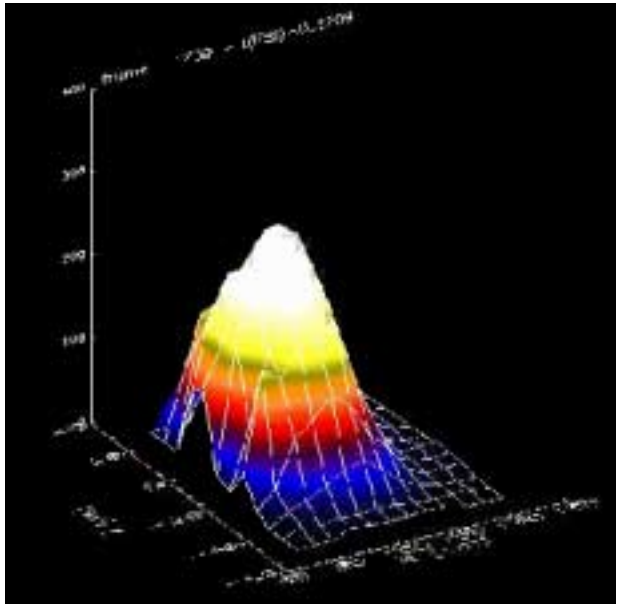
FAST CORE MHD

wide view 80*80 cm

Spatial resolution : 6.5 cm

Framing rate : up to 50 (100) khz

Examples:
inner modes, rotating islands, sawtooth, IRE ..



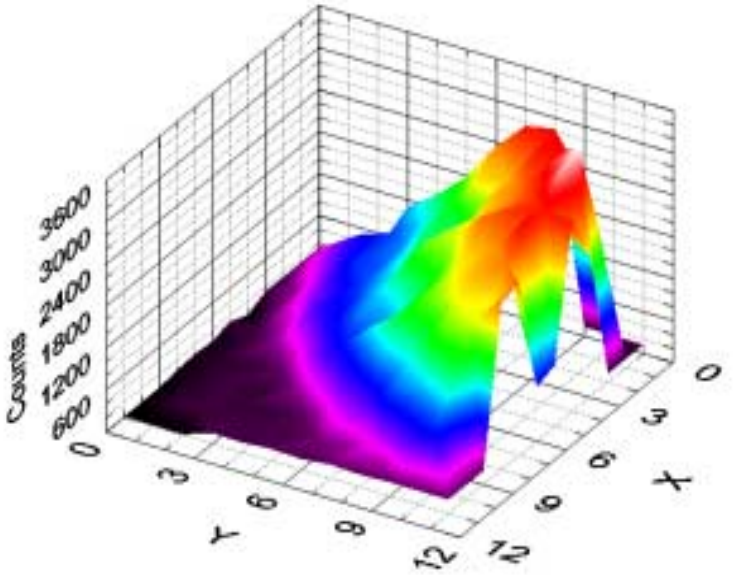
SLOW CORE MHD

zoom 40*40 cm (20*20)

Spatial resolution : 3 (1.5) cm

Framing rate : up to 5 khz

Examples:
magnetic surface curvature, q0, asimmetries….

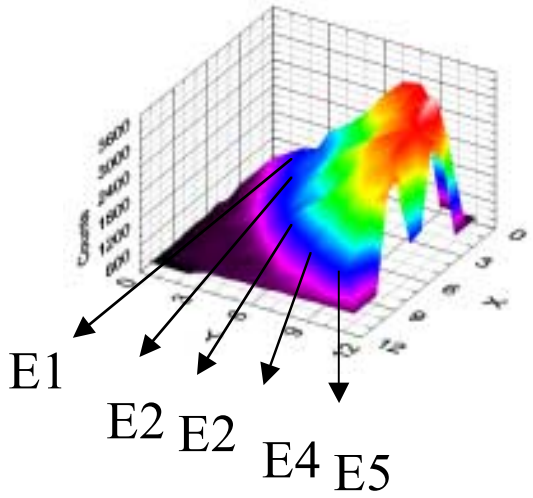


Perturbative transport

Perturbation of the spectral X emissivity on the magnetic surfaces

2-D

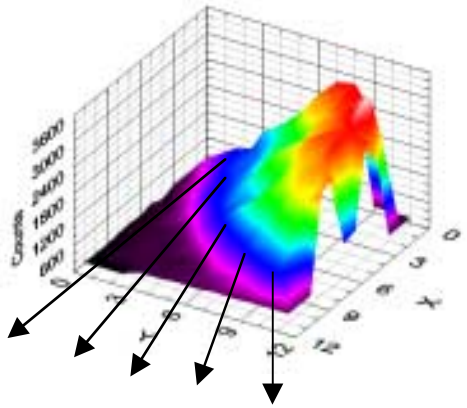
Rate : 1-5 khz



Different energy thresholds

1-D

Rate : 10-50 khz



Spatial integration

2 D temperature map

Proof of principle checked on NSTX

Time resolution : 20 ms

RF heating effect ?

At the present no data available because of the RF noise on the bare electronics

Possible contributions:

Asymmetries in the X-ray emissivity

Spectral changes (temperature)

SUMMARY

- a novel system has been validated in a 2-D view of the plasma (NSTX), particularly useful for spherical tokamak
- it combines spatial imaging capability with energy discrimination
- adjustable energy range: 1- 8 keV (0.2-60 keV)
- high time resolution (up to 100 Khz), extremely high dynamic range (300)
- large flexibility in imaging: zoom and changes of the spot
- It can be used for core MHD, perturbative transport, electron temperature and RF heating effects

A new system with 1024 pixels is under developments